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DEEP SKY

Gas Clouds in Galaxies

Observing the Local Group

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DEEP SKY

The Magazine for Deep-Sky Observers and Astrophotographers

Fall 1983 Volume 1, Number 4

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Cover: The "Pinwheel" galaxy M33 in Triangulum is the nearest face-on spiral to us and a keystone of our Local Group of Galaxies. It offers the most detail to backyard observers than any spiral in the sky; its enormous gas clouds, swarm of globular clusters, array of stellar associations, and brightest stars show up in large amateur scopes under dark sky conditions. Al Lilge made this photo of M33 using a 12.5-inch f/8 Ritchey-Chretien, 098 emulsion, and a 120 minute exposure. This page: M33's appearance through moderate size backyard telescopes. Sketch by Dave Eicher.

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Letters to DSM

Deep-Sky Dreaming

Dear Dave / In my fantasies, I roam the universe with the aid of my trusty ol' 13-inch Dobsonian. I observe intricate detail within spirals, find NGC 4138 harboring a supernova, split double stars only dreampt of afor and discover a new comet — all in one evening!

But back on Earth, I have problems. My largest scope is only a 4½-inch f/8 reflector. Not to belittle this instrument, after two years it still has a long way to go before its full potential is reached. My problem does not lie in the objective's diameter, but in useful information on what to observe. In astronomy magazines and books, articles seem "geared up" for the big guys. It's nice to know that NGC 4424 looks great in a 14-inch SCT — but what does it look like in *my* eyepiece? Is it worth searching for, or will it be just too dim, or possess too small an angular size?

So I was pleased this morning to open up DSM and find "Scanning the Summer Skies." I must admit that I am familiar with many of the objects listed, but I found the article interesting and — in the case of the Barnard and Lynds clouds — very informative. I hope this article is the forerunner of many for us smaller scope owners.

I must also thank you for a) "Galaxies Around the Great Bear" and b) introducing me to double star observing. This is something I have not become too involved in yet, but over the past few months it has become an area of observing which has brought me great

Bart Jan Bok

April 28, 1906 — August 5, 1983

The last issue of DEEP SKY contained an interview with Bart Bok, which made many readers — including Bart himself — very happy. We are now grieved to report that the great master of the Milky Way died of an apparent heart attack at his home in Tucson, on Friday, August 5.

"I started out as an amateur," Bart used to say. "I then became a professional, and now that I am retired I am an amateur once more." Perhaps more than most professionals, Bart Bok knew what it meant to look up at the stars and planets. "Have you seen Jupiter rising yet?" he would challenge me. He jumped right in, enthusiastically answering himself, "Yes, yes. *I* did. Yesterday morning, at 5 a.m."

We are all familiar with Bart's legendary accomplishments in astronomy — an early association with Jan Oort in his native Holland, his publication of *The Milky Way*, his Directorships of Steward and Mount Stromlo Observatories and his earlier accomplishments at Harvard College Observatory, where he was a colleague of Harlow Shapley. Bart Bok was one of us, a scientist who was in astronomy for all the right reasons. He once told me with pride how he was the third of a line of observers who discovered the globules which now bear his name. "First, of course, there was Herschel, and then Barnard observed them. You know Barnard — one of the great observers of all time. And then — B.J. Bok! But what should we call them, these holes in space? One day, the milkman had delivered the then unhomogenized milk, with globules in the cream at the top. That's it! Globules!"

Bart loved to lecture — on any astronomical subject, on any continent. His favorite topics were "The Bigger and Better Milky Way" (of course) and the formation of stars. And as you may recall from last issue, he also looked forward to "The Promise of the Space Telescope." Possibly his finest lecture happened at Riverside in 1981. His slides had just been stolen, but that did not bother him. He was on top of a 7500-foot mountain, a 75-year-old with a weak heart, but that would not stop him either. "No problem, I'll talk with gestures," he announced with a triumphant wave of his hand and a childlike grin on his face.

During the last two years I have collected hours of taped interviews for his biography. We met at his home for an hour or two each week, usually over drinks. "You can't do a biography if you don't drink, David. Boswell did Johnson in a tavern!" Fortunately the tape stayed sober, and I now have many hours' worth of stories that describe a pattern of greatness, the story of one of the finest people I have ever known.

At the end of each interview, Bart came to the front door to wave goodbye as I drove off. On Monday, August 1, Bart saw me to the door. "Don't forget to watch me wave goodbye at you," he said, "It's what I always do." — *David H. Levy*

pleasure — thanks to Glenn's regular articles.

Also, I would like to express my thoughts on a letter from Mr. U. Schlegel in DS #1, concerning Keeler 330 "within" M97. Last spring, I felt myself lucky to actually locate M97, and since then it has become a favorite planetary nebula of mine. Thus, I was intrigued to read of K330. Trips to the local university and central reference library allowed me to dig up a couple of handy reference books including the MCG. On reflection, it seems to me that this object *is* a far distant galaxy, with the Owl "superimposed." The chances are not as small as one might think — look at the apparent association between M46 and NGC 2438.

I do not agree with Mr. Schlegel's suggestion that K330 is a far distant HII region. It would be very strange to find such a region far from its "home" in the Galactic plane. It may be a Herbig-Haro object, maybe even in some way connected to the planetary, but this is purely speculation.

I'd like to close by saying thanks to your good self and all your staff for bringing the magazine into being — I know that it will continue to be of excellent use to me, especially when I get that 13-incher!

David Benn
8 Old Farm Approach
Leeds, West Yorks U.K.

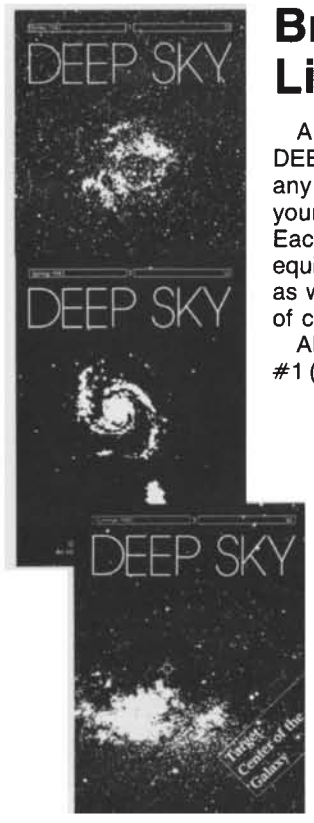
Photographs *vs.* Sketches

Dear Mr. Dave Eicher / I enjoy your magazine very much because of the in-depth coverage of deep-sky objects. There is no other magazine available to observers or astrophotographers which covers most of the objects in a particular constellation. I do my observing by constellation and use an Odyssey 1 to star-hop to objects.

I was a subscriber to your old magazine *Deep Sky Monthly* which I also enjoyed very much. In that magazine you had many more sketches than photographs and now the reverse is true. I am beginning to make sketches and would like to see more of them in your magazine, as well as an article on how to sketch. Your new magazine seems to have too many photographs.

Dennis E. Hoverter
118 Maplewood Lane
Maytown, PA 17550

Mr. Hoverter / I would be happy to run more sketches in DEEP SKY and an article on how to sketch deep-sky objects (for the latter, see the February 1983 ASTRONOMY*). I have a fair collection of sketches that have already been used in the old* Deep Sky Monthly*, and would be happy to receive new sketches from observers like you.*



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Inside View

Growing Pains

Let me start off by saying that I am thrilled with the response I've received to DEEP SKY magazine — a year ago I never seriously thought that the management at AstroMedia would have gone for a new magazine about deep-sky observing. DSM existed for five years as a private non-profit venture that was enormously popular with a small contingent of observers but never stood on its feet financially. That's not to say that the marketplace for a deep-sky magazine isn't there — certainly it is since deep-sky is now the most popular subset of astronomy — I just didn't think they'd "go for it."

But they did, thanks to Richard Berry. Consequently, DEEP SKY has grown quite a bit. In just three issues, we've nearly tripled our circulation and have, I hope, brought deep-sky observing to a whole new class of people who never seriously did much of it. Just as TELESCOPE MAKING injected new life and vigor into amateur scope building, I think that DEEP SKY is now in a position of influencing deep-sky observing and photography in a very positive way.

Out of all the letters I get about DSM, the commonest are those which ask for a *bigger* DSM, and that's exactly what I'd like to provide. I'd like to be able to include more sketches,retain the meaty observing articles, and still add lots of information about astrophotography. But I can include only so much in 36 pages — five of which belong to the advertising department.

Even though DSM has been around for six years, it is a new magazine in its present incarnation. As with any new magazine, we always worry a bit when the first batch of subscribers comes up for renewal. If you enjoy what DEEP SKY has to offer, please "vote with your wallet" and extend your subscription now. DEEP SKY cannot exist without support from its readership. A solid vote of confidence from you, the readers, will keep DEEP SKY charging ahead and growing vigorously.

Warm regards,

Dave Eicher

Dave Eicher
Editor

Deep within most spiral galaxies are collections of HII gas clouds that dwarf the Orion Nebula by comparison. These giant hot clouds provide us with critical information about starbirth, chemical properties of galaxies, and the distance scale of the universe. Artwork by Mark Paternostro. *Inset*: The Milky Way gas cloud NGC 3603 photographed with Cerro Tololo's 4-meter reflector. Courtesy B. Balick, G. Boeshaar, and T. Gull/CTIO.

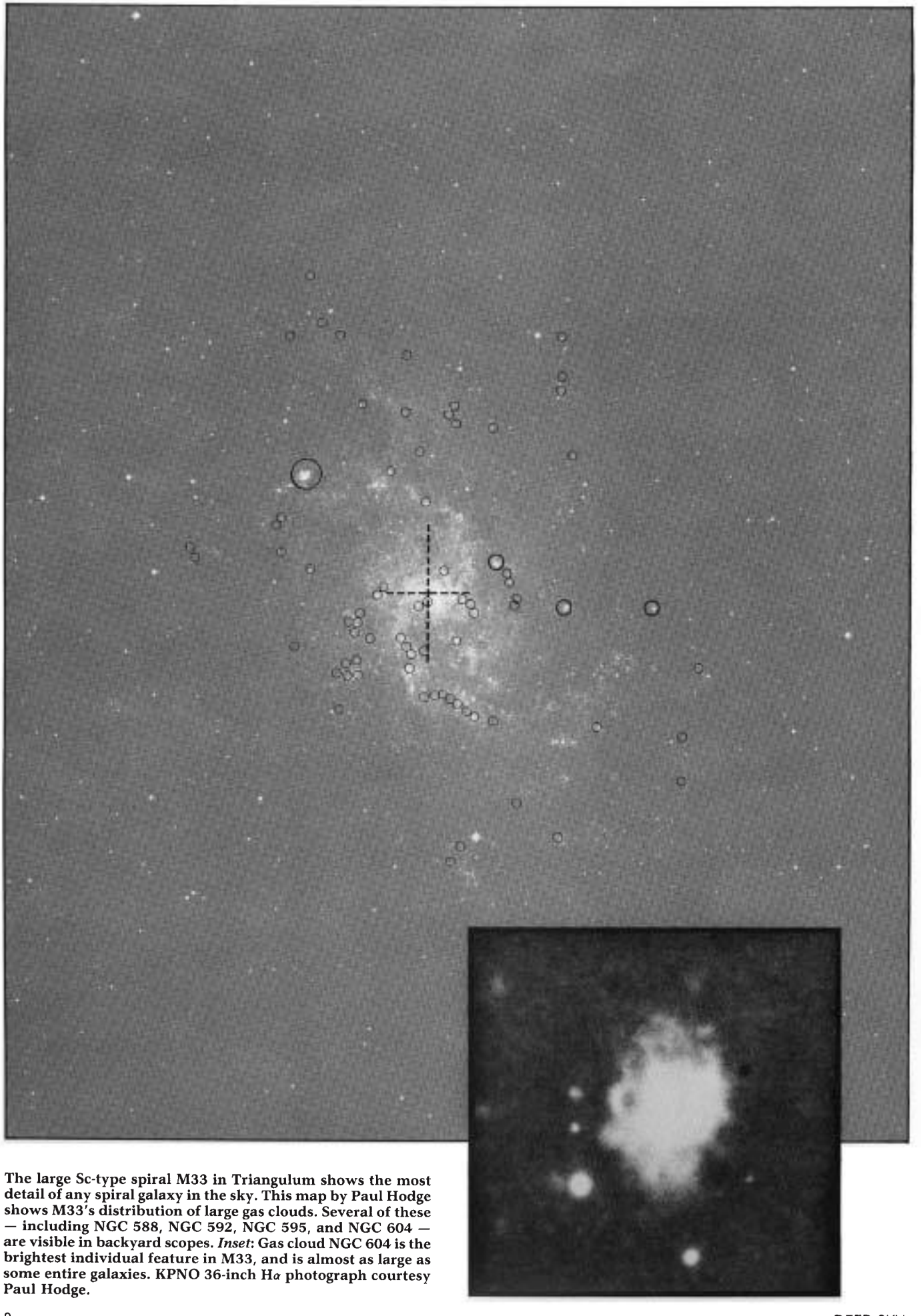
GAS CLOUDS in GALAXIES

The Orion Nebula (M42), a favorite object for deep-sky observers, measures about 40 light-years across. This sounds large, and it certainly is when compared to stars or even most open star clusters. But as glowing gas clouds go, M42 is a small, faint, inconspicuous example: the largest and brightest gas clouds in galaxies are as much as a hundred times its size. If one of these objects were located as close to the Sun as the Orion Nebula, it would cover a large part of the sky and would glow brightly enough to cast shadows on moonless nights.

Most of these super-bright clouds in our Milky Way Galaxy are invisible to us optically, hidden from view by the deep layers of dust that surround us in the Galactic disk. One that can be seen — though only from the southern hemisphere — is NGC 3603, a bright, immense cloud of gas lit up by a whole cluster of hot stars embedded in it. It is a distant object, glimpsed through a relatively clear patch of Galaxy from 30,000 light-years away. Wisps of delicately-structured nebulosity, part of a much nearer complex of gas and dust, lie to one side of it, like drawn curtains enabling us to peer deeply into the hidden reaches of our Galaxy.

Recently Bruce Balick of the University of Washington, Greg Boeshaar, now associated with the Space Telescope, and Ted Gull of NASA studied NGC 3603, and showed that it is composed of a dense central region about 25 light-years across, surrounded by a faint outer halo 170 light-years in diameter. The central area has a density of about 1800 electrons per cm^3, while the outer part is much less dense, averaging about 100 electron per cm^3. Throughout the nebula, supersonic turbulent winds throw particles with velocities of about 40 km/sec (about 90,000 miles per hour). A small wind-driven gas bubble — formed by the hot cluster stars' stellar winds — surrounds the central star cluster.

by Paul W. Hodge



The large Sc-type spiral M33 in Triangulum shows the most detail of any spiral galaxy in the sky. This map by Paul Hodge shows M33's distribution of large gas clouds. Several of these — including NGC 588, NGC 592, NGC 595, and NGC 604 — are visible in backyard scopes. *Inset*: Gas cloud NGC 604 is the brightest individual feature in M33, and is almost as large as some entire galaxies. KPNO 36-inch Hα photograph courtesy Paul Hodge.

Although it is much more distant than M33, the galaxy NGC 2403 in Camelopardalis offers a view of similarly knotty, dusty loose spiral arms. Although the gas clouds in NGC 2403's arms are difficult to visually observe, a large Dobsonian at high power may do the trick. Photo by Lee C. Coombs. *Inset*: At Kitt Peak, Paul Hodge used a 36-inch scope with image tube and Hα filter to create this image of NGC 2403's gas clouds — representative of enormous star forming regions in the galaxy.

We know that our Galaxy contains many more giant clouds of gas — even larger and brighter than NGC 3603 — but they are totally obscured by dust, and thus are detectable only by radio and infrared telescopes. It is actually easier to see giant gas clouds in other galaxies than those in our own.

The easiest of these to observe in small telescopes is, unfortunately for northern observers, also in the far southern skies. Visible to the unaided eye on a dark night, the spectacular Tarantula Nebula (also known as 30 Doradus) is the brightest gas cloud in the nearest galaxy to us, the Large Magellanic Cloud. As bright as Orion but over a hundred times farther away, the Tarantula Nebula gets its energy from the ultraviolet light of hundreds of super-bright hot stars in it, including one that may have 2000 times the mass of the Sun. With a small telescope, the nebula is a glorious object: it is a large bright patch, stretching across the field of view and surrounded by unresolved star clusters and the faint nebulous structure of the LMC's bar. In larger telescopes its filamentary "legs" become visible, and the surroundings resolve into hundreds of supergiant stars.

Lately the Tarantula Nebula is in the astronomical news, primarily because of a discovery made with an orbiting telescope, the International Ultraviolet Explorer. Joe Cassinelli, John Mathis and Blair Savage of the University of Wisconsin studied the ultraviolet spectrum of the Tarantula's central stellar image (known as R136 or HD 38628 in astronomers' catalogues). This image is actually made up of several extremely hot stars, the brightest of which is R136A. The Wisconsin astronomers' analysis shows that this object is probably a single star with staggering properties: its temperature is 60,000° K, its luminosity is 100 million times that of the Sun, and its total mass is at least 200 times the Sun's. An immense stellar wind shows up in the spectrum, with a 3500 km/sec outflow of gas (about 8 million miles per hour). It is the ultraviolet light from this unique star that appears to be responsible for lighting up the entire Tarantula Nebula.

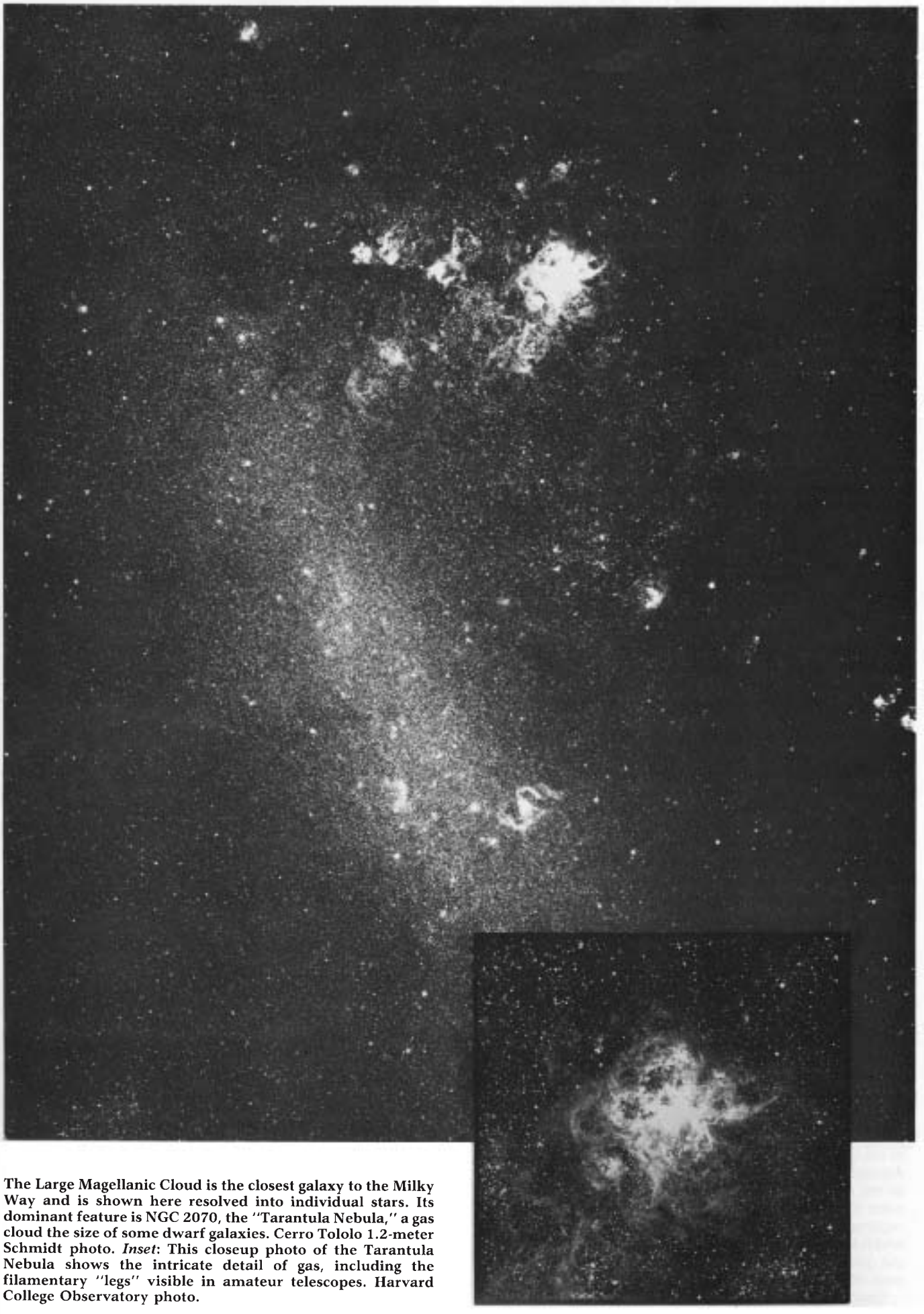
For northern hemisphere observers there are similar objects in the sky, though they lie in galaxies at least ten times farther away than the Large Magellanic Cloud. The Triangulum Galaxy (M33) contains three giant gas clouds visible as such with moderate-sized telescopes. The brightest is NGC 604, a real rival for the Tarantula and a brilliant hotbed of new star formation. Somewhat fainter and more difficult are NGC 592, NGC 588 and NGC 595 (see map on page 8). Try your luck with at least a 6-inch telescope under dark skies. If you can see these objects, remind yourself that you are looking deep into a galaxy over two million light years away.

NGC 604, as the brightest extragalactic HII region visible in the northern hemisphere, is a thoroughly studied object. Recently Sandro D'Odorico of the European Southern Observatory and Michael Rosa of Heidelberg University — who discovered almost 50 Wolf-Rayet stars embedded in it — pointed out its similarity to 30 Doradus. The Wolf-Rayet stars are extremely hot and show characteristically massive stellar winds: R136A may be an extreme example. Peter Conti of the University of Colorado and Phil Massey of the Dominion Astrophysical Observatory find that most of the bright knots in the nebula (and the other bright M33 clouds) show that such stars are present. The extensive work on M33's HII regions by Georges Courtes and his colleagues at Marseilles, which led to a catalogue of 369 different gas clouds, confirms the giant nature of NGC 604. Its image greatly dominates any map of M33.

Searching for such objects in the other great nearby spiral galaxy, the Andromeda Galaxy (M31), would be a mistake, however. It simply doesn't have any gas clouds as huge and bright as the biggest in M33. As in other galaxies of its type, there are hundreds of smaller nebulae like Orion and even somewhat brighter, but the true giant gas clouds are missing.

Although even farther away, the spiral M101 has, just beyond its faint outer arms, a gas cloud so immense that it can be seen with a moderate-sized telescope. Named NGC 5471, the object is so bright and large it almost could be considered a galaxy itself, though it is embedded in the neutral hydrogen gas disk of M101. The distance to this galaxy is still uncertain, but surely it is more than 10 million and might be as much as 20 million light-years from the Sun.

If you take a large telescope and equip it with an electronic

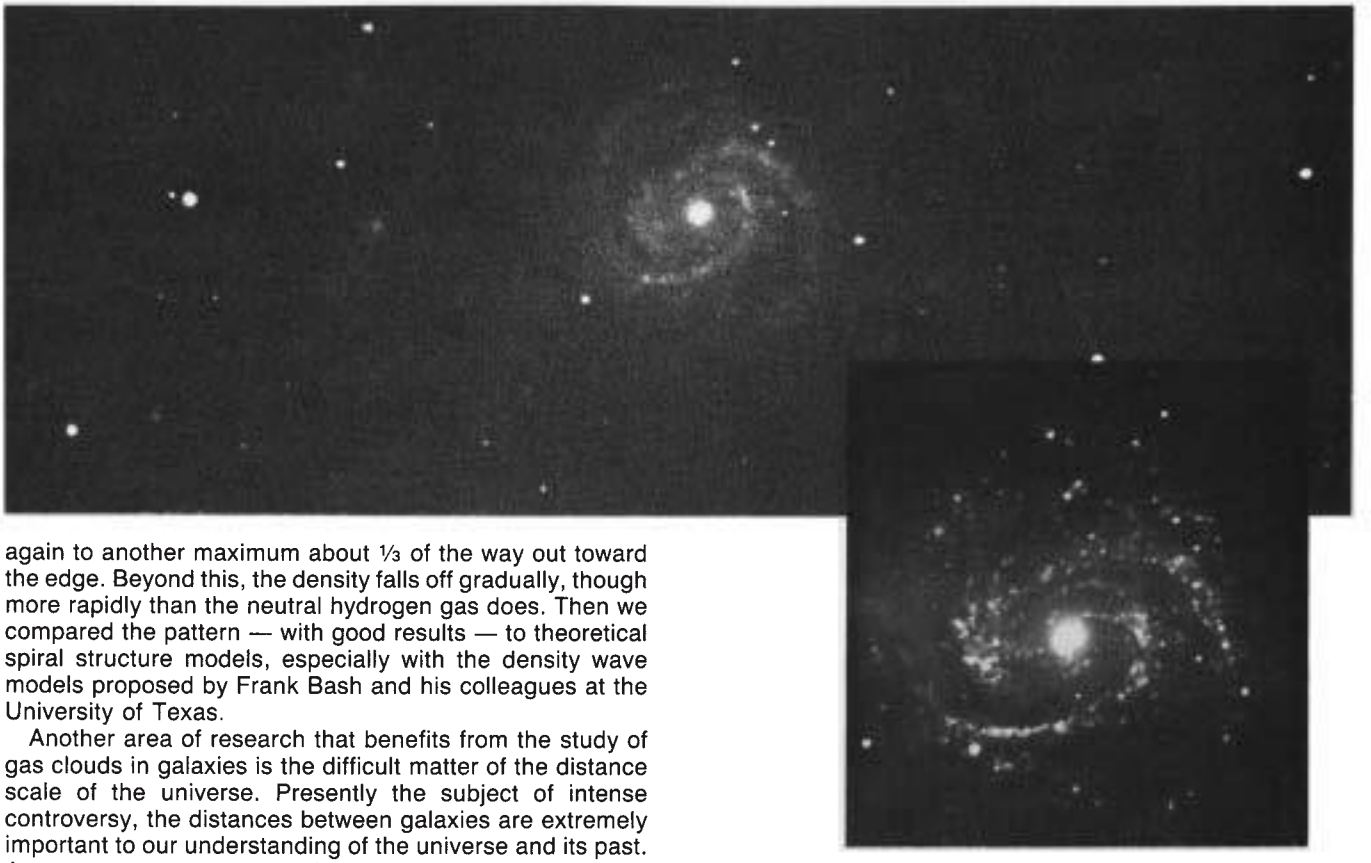


The Large Magellanic Cloud is the closest galaxy to the Milky Way and is shown here resolved into individual stars. Its dominant feature is NGC 2070, the "Tarantula Nebula," a gas cloud the size of some dwarf galaxies. Cerro Tololo 1.2-meter Schmidt photo. *Inset*: This closeup photo of the Tarantula Nebula shows the intricate detail of gas, including the filamentary "legs" visible in amateur telescopes. Harvard College Observatory photo.

image intensifier and narrow-band filters to isolate the hydrogen lines of the light emitted by the gas, you can detect hundreds of gas clouds in galaxies as far away as 50 million light-years. And these clouds enable us to study many interesting galactic problems. For example, the nature of spiral structure and patterns of star formation in galaxies are now under investigation: the gas clouds are especially useful because both gas and very young, hot stars exist in the arms. Spiral arms in many galaxies seem to be clearly delinated by concentrations of star formation events, and we can check current hypotheses about spiral arms to see how well they conform to the facts.

As an example, consider the beautiful Virgo spiral M100 (NGC 4321). Scott Anderson and I, working with Rob Kennicutt of the University of Minnesota, recently published an analysis of its spiral structure based on the 286 gas clouds we had discovered in it. By fitting logarithmic spirals to our HII region arms, we found that the galaxy is inclined to the line of sight by 56°. There is a high density of excited gas clouds in an inner spiral pattern near the nucleus, with an inactive area outside of it, beyond which the density rises

M100 is a rather distant Sc-type spiral in the Virgo Cluster of galaxies. It is a difficult object for backyard telescopes, revealing only a condensed oval nucleus with a faint mottled haze. Photo by Martin C. Germano. *Inset*: Scott Anderson and Paul Hodge made this photo of the gas clouds in M100 by using a 36-inch KPNO reflector and an Hα bandpass filter. The galaxy shows a high concentration of clouds near the nucleus. Are any of these even remotely visible in large amateur scopes?



again to another maximum about ⅓ of the way out toward the edge. Beyond this, the density falls off gradually, though more rapidly than the neutral hydrogen gas does. Then we compared the pattern — with good results — to theoretical spiral structure models, especially with the density wave models proposed by Frank Bash and his colleagues at the University of Texas.

Another area of research that benefits from the study of gas clouds in galaxies is the difficult matter of the distance scale of the universe. Presently the subject of intense controversy, the distances between galaxies are extremely important to our understanding of the universe and its past. Astronomers use every method they can find to measure galaxies' distances, and one that has turned out to be particularly useful is utilizing sizes of gas clouds. Galaxies of a given type have similar gas cloud populations. Since the largest gas clouds are visible in galaxies as far away as 50 million light-years, they provide a way to estimate distances over a large portion of the local universe.

Jorge Sersic of Cordoba Observatory in Argentina and Allan Sandage of Mount Wilson and Las Campanas Observatories first proposed this method of gauging distances. It prominently figures in the recent elaborate distance-scale framework that Sandage and Gustav Tammann of the University of Basle, Switzerland, have put together. They derived a scale parameter for the universe — called the Hubble Constant because it relates galaxies' distances to their Hubble expansion velocities — of 50 km/sec/Mpc (about 15 km/sec/million light years). This result is not universally accepted, however. Rob Kennicutt, who remeasured HII region properties of the Sandage-Tammann galaxies, derived a value of 65 km/sec/Mpc, and others using various other methods, such as Gerard de Vaucouleurs of the University of Texas, find larger values yet, on the order of 100 km/sec/Mpc. Hopefully a more complete study of HII regions will eventually help to a resolve this controversy.

Gas clouds are a prime source of information on the chemical abundances in galaxies. For the Magellanic Clouds, for example, the spectra of the emitting gas show that there are fewer heavy elements than for the Sun and its neighbors (including the Orion Nebula). For other galaxies, such as M101, spectra of the gas show a trend of composition, with the inner parts of the galaxies richer in heavy elements than the outer. Astronomers believe this is due to the higher frequency of stellar formation, evolution, and death that occurs in the central, denser parts of galaxies. And heavy elements are produced inside stars; when stars die, they are dispersed into space to be used for new stars.

The next time you look at a photo — or better yet, a "live" image — of the Orion Nebula, remember that it is a mere midget among gas clouds. Its giant cousins are a hundred times as big and thousands of times more luminous. Like brilliant gems gleaming in and between spiral arms, they help to provide insight into the nature of galaxies and the size of the universe.

Paul W. Hodge is Professor of Astronomy at the University of Washington and the author of many scientific books and papers. His research specialties include studying star clusters in M31 and the Magellanic Clouds, and observing HII regions in nearby galaxies.

Observing the Local Group

by Alan Goldstein

Of the thousands upon thousands of galaxies that pepper the heavens, several hundred can be seen in telescopes of 6-inches' aperture or less. Of those hundreds, the brightest galaxies are those in our own Local Group of Galaxies, a gathering of about 30 galaxies that range in size from large systems like the Milky Way down to "dwarf" galaxies such as Leo II. Now is an appropriate time to go looking for them, since most of the Local Group objects which are visible in small telescopes can be found in the skies of autumn and early winter. (See table on page 15.)

Excluding our own Milky Way, the most conspicuous member of the Local Group visible from mid-northern latitudes is the **Andromeda Galaxy**. Also designated Messier 31 and NGC 224, this galaxy can be seen easily without optical aid in dark skies. It appears as a rather amorphous spot about 7° north-northwest of 2nd magnitude Beta (β) Andromedae. With slight optical aid (such as a pair of binoculars or a spotting scope), its oval shape becomes evident.

M31 has the distinction of being the most distant object visible with the unaided eye; it lies 2.25 million light-years away. The light you see tonight left the galaxy when early man and woolly mammoths were wandering the Earth. (Purists note: the light from the near side of M31 is approximately 100,000 years younger than the light from the far side, because of the galaxy's large physical size.) It's always a little staggering when you remind yourself that that soft glow actually represents the combined light of several billion stars!

With the naked eye, the galaxy spans some 5° end to end. To try determining its extent for yourself, an easy nearby comparison is the separation of Nu (ν) and Mu (μ) Andromedae which lie to the east and south of M31, and are almost exactly 2½° apart. In binoculars and spotting scopes, the Andromeda Galaxy's shape is distinctly "galaxy-like" and it is interesting to trace the outer parts as far as you can using averted vision. You'll notice the bright central hub, though the nucleus itself still lies out of reach.

Small optics will also be useful for picking up a supernova, because you avoid the clutter of hundreds of foreground stars that larger instruments provide. In 1885 a supernova was observed near the nucleus. At 7th magnitude when discovered, it had already passed its peak brightness, estimated between 6 and 6.5 magnitude. Considering the size and mass of M31, it is not unreasonable to expect — or at least hope for — another supernova before the year 2000. So long as it is not buried deeply in the dusty gas and heavily obscured, an "average" supernova should peak at more than 8th magnitude. If you make a habit of observing the galaxy, you'll learn the starfields around M31 — and any "new" stars will be relatively easy to spot.

M31 has at least two companion galaxies, **M32** and **NGC 205**, which may be visible in small optics under dark skies. I've seen both in a 40mm spotting scope at 20x, though admittedly the sky conditions happened to be unusually good. You'll find that a tripod or some other brace is necessary since the small angular diameter of M32 and the low surface brightness of NGC 205 make observing them difficult when the instrument isn't rock-steady in your hands.

In telescopes of 3- to 6-inches' aperture, the M31/M32/NGC 205 trio is a very beautiful deep-sky "object" — certainly the best extragalactic view in the northern hemisphere. The dominance of M31 is unmistakable and it requires little imagination to see its two smaller companions swarming around the larger galaxy. Photographs show that M32 is actually on the fringes of the Andromeda Galaxy. In small telescopes, however, the connection is too faint to see directly.

Six-inch telescopes begin to show some structural detail within M31. **NGC 206**, a large starcloud on the galaxy's northwestern edge, can be glimpsed under extremely favorable skies, as can the dark lanes which lie on the near side of the galaxy. With yet-larger telscopes the dark lanes help give a three-dimensional appearance, and you get the impression that the dark lanes of dust cut across the glow from more distant stars — which is exactly what's happening.

M32 is an elliptical galaxy and appears nearly circular with a high surface brightness. This galaxy can be observed at very high magnifications, though no structural detail can be seen with any amateur telescope. NGC 205 is the opposite of M32 in many ways. Both are dwarf elliptical galaxies, but 205 has a low surface brightness and does not bear magnification very well. It is easily obliterated by light pollution and consequently is difficult to spot from suburban locations. If you find NGC 205 to be fairly easy, try for two other dwarf ellipticals about 6° north of M31: NGC 147 and NGC 185.

NGC 147 and **NGC 185** are a pair of galaxies having low surface brightnesses. NGC 185 lies just one degree west of

Just as the Magellanic Clouds rotate about the Milky Way, the tiny ellipticals M32 and NGC 205 (shown here) satellite in orbit around our sister spiral, the Andromeda Galaxy. Tom Dessert made this photo using a 10-inch f/6 Newtonian, 103a-F emulsion, and a 30 minute exposure.

Omicron (ο) Cassiopeiae and NGC 147 lies a degree farther to the west. NGC 185 is the rounder of the two and is slightly smaller in apparent diameter than M32. NGC 147 is somewhat larger, more oval, and shines about 1.5 to 2 magnitudes fainter because it has a lower surface brightness. Both can be picked up in a 6-inch telescope and even a 4¼-inch will do under extremely dark skies. Both galaxies are part of the Andromeda "subgroup," despite their apparent isolation from M31.

After M31, perhaps the most interesting Local Group member is a galaxy some 14° to the southwest. **M33** is an open-faced Sc spiral with a lower surface brightness than M31. In photos it displays two features typical to Sc type galaxies: it has a small nucleus and fairly open and conspicious arms. In addition, M33 is much richer in starclouds and HII regions (emission nebulae).

Several observers have reported seeing M33 with the naked eye. It is certainly much more difficult to see than M31, as it has an integrated magnitude of 6.8 (compared to M31's 4.8) yet it spreads over a similar area. Observers in New England and Arizona have reported seeing it naked-eye, though I have not seen it personally. It is probably visible with

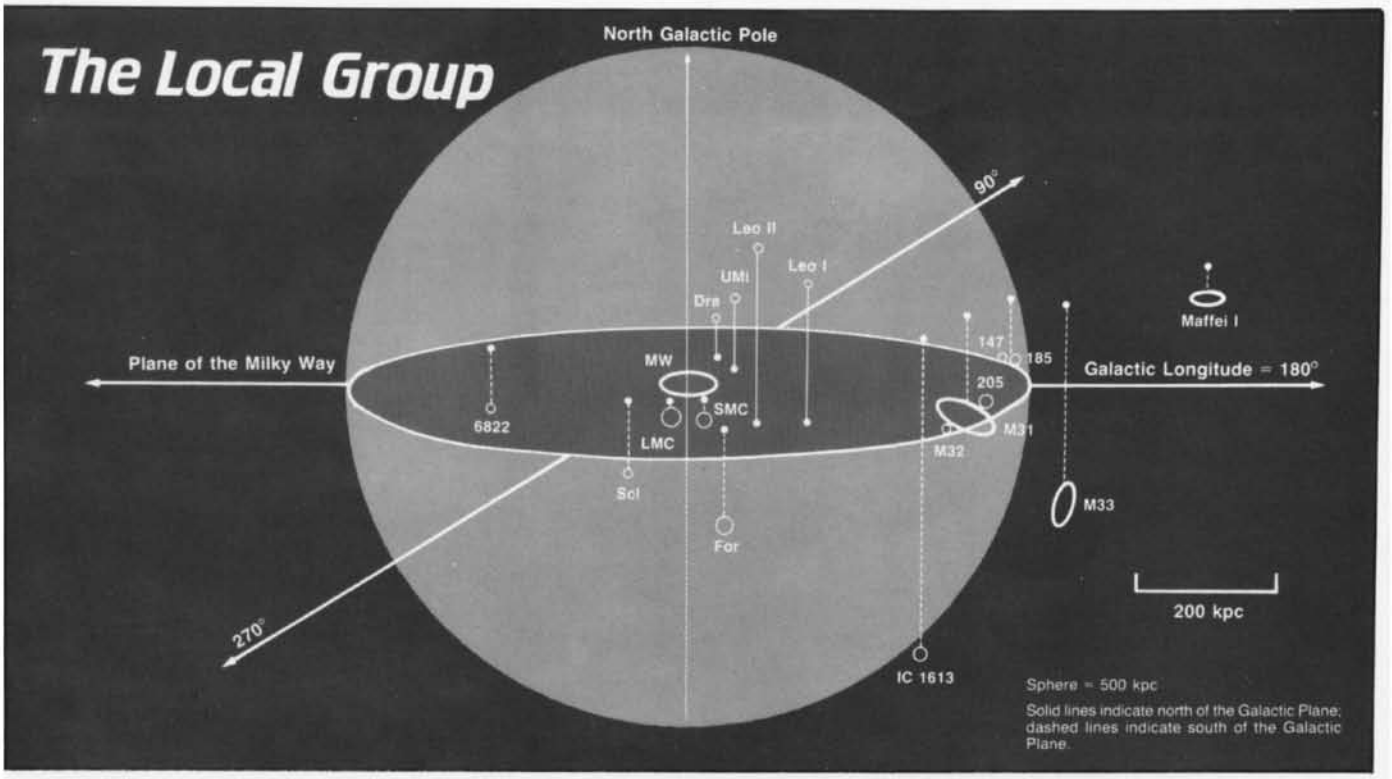
The Magellanic Clouds

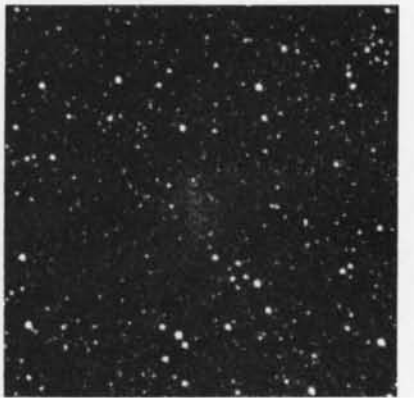
Two very important members of the Local Group cannot be seen by most northern hemisphere observers — the Large and Small Magellanic Clouds.

These are true celestial showpieces, since both lie relatively nearby: the Large Cloud at 180,000 light-years, the Small at 200,000. The closer and physically larger of the two, the Large Cloud reveals more individual features and consequently is an awesome sight in binoculars and small spotting scopes as well as in larger telescopes. Instruments from 3- to 6-inches' aperture resolve many stars and show many of the fainter star clusters as bright patches. The famous Tarantula Nebula (NGC 2070) is a huge emission nebula and stellar association that is an easy target for any optics. Many of the nebulae and clusters in both the Large and Small Clouds have NGC and IC designations.

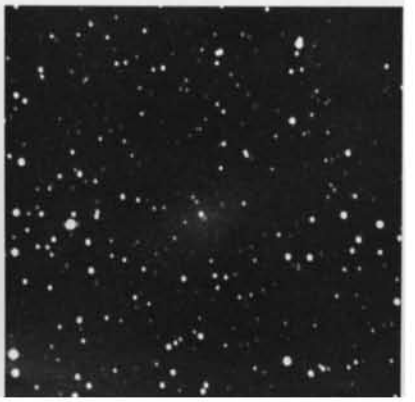
If you are traveling to the southern hemisphere, either on vacation or business, be sure to carry at least a pair of binoculars with you, as this southern circumpolar pair is well worth looking at. We certainly have reason to envy those who can observe the Magellanic Clouds! Now why couldn't they be put, say, at the celestial equator, for all of us to see. I wonder if I can get my Congressman to introduce some legislation . . . .

Harvard College Observatory





Left: At a distance of 2.4 million light-years, M33 is the nearest face-on spiral galaxy. Photo by Akira Fujii, who used a 12-inch f/5 Newtonian, hypersensitized TP 2415, and a 15 minute exposure. *Above:* Discovered by Barnard, NGC 6822 is a galaxy notoriously difficult to observe. John Sanford made this photo with a 5.5-inch f/1.65 Schmidt camera, Tri-X film, and a 10 minute exposure.



Far Left: The problem with observing the Leo I dwarf galaxy is its close proximity to Regulus. Photo by Martin C. Germano, with a 5.5-inch f/1.65 Schmidt Camera, hypersensitized TP 2415, and a 5 minute exposure. *Left*: Another low surface brightness object is NGC 147, observable with a 6-inch scope on good nights. Roger Sliva took this photo by exposing 103a-O for 19 minutes with his 12.5-inch f/5 Newtonian.

the naked eye anywhere you can get truly black skies.

If the naked eye doesn't pick it out, a little optical aid will usually suffice at dark-sky locations. (Its low surface brightness makes M33 a very difficult or impossible object from nearly all urban and many surburban areas.) A small telescope can easily pick up an amorphous patch about 5° west of Alpha (α) Trianguli. Since it has an apparent diameter of 65′x45′, you'll find low powers work best. Many features — indeed the galaxy itself — tend to vanish under high magnification.

A 6-inch will reveal the faintest traces of spiral structure, and a slight nuclear brightness is visible with smaller optics. Nor is that all the structure visible: If we exclude the Magellanic Clouds, M33 contains the brightest extragalatic HII region observable with any small telescope: **NGC 604**, which is pretty easy with a 6-inch. To me, it looks like a bright nebulous patch at about 10th magnitude. It's generally round in shape, and considering its immense distance, it is one of the largest nebulae in any galaxy. This 1,000 light-year diameter "Orion Nebula" lies 10 minutes of arc northeast of M33's center.

There are many other starclouds and HII regions visible within this galaxy, but they are beyond the grasp of small telescopes. An interesting project for large telescope owners would be to place aperture masks over the instrument and try to determine the smallest possible aperture needed to view the various objects within M33.

Now swing your scope from M33 back to Beta Andromedae. With the star in the center of the field, try to spot the elusive **NGC 404**, a small round lenticular galaxy that may be a member of the Local Group. Its published magnitude is relatively bright — 10.7 — but this is misleading since NGC 404 lies a scant 4 arc-minutes north and 20 seconds in right ascension west of Beta, a 2.4 magnitude star! NGC 404 is easier to see than Sirius B, but nonetheless it is a tough challenge for small telescope users.

It can be picked up fairly easily in a 6-inch with high powers. The technique I use is to search until I suspect I've found the galaxy, then shift the tube to put the star out of the field of view. If you have in fact found NGC 404, it will become more distinct once the bright star is out of field. I have observed this galaxy with a large telescope on occasion, when I can effectively remove any trace of the star by using 250x. NGC 404 has a high surface brightness, so it bears magnification well. Experiment with various magnifications to find the best view for you. I would be interested in hearing from observers using telescopes with apertures from 2.4-inch to 4¼-inch who observe NGC 404.

Of the remaining Local Group members only three dwarf galaxies offer much hope of being seen. They all have very low surface brightnesses and only the best nights should be used. The three objects are IC 10, IC 1613, and the Fornax Dwarf.

IC 10 is a faint dwarf irregular near Beta Cassiopeia. It is isolated, and while fairly close to the NGC 147/NGC 185 pair, is not part of the Andromeda "subgroup," but lies beyond at nearly 4 million light-years' distance. A 6-inch might be enough under the darkest skies to pick it up. This galaxy has about the same angular size as NGC 185.

IC 1613 is probably a little less difficult than IC 10. It lies in the constellation of Cetus and is frequently called the Cetus System. IC 10 is an irregular galaxy consisting of several distinct patches of stars, which astronomers have interpreted as the result of different spurts of star-formation. Unlike IC 10, the Cetus System is poor in HII regions, which means star-formation is apparently over — at least on a large scale. IC 1613 is only slightly more difficult than NGC 6822 in western Sagittarius. I have observed the latter under excellent skies with a 6″ f/8 at low power.

The Fornax Dwarf is a small low-mass spheroidal galaxy. If you took the Omega (ω) Centauri globular cluster, enlarged it 100 times, and then removed 90% of its stars, you would have the Fornax Dwarf. Its integrated magnitude is estimated to be 9, but that's very misleading, since the galaxy has an apparent diameter of about a degree. Four Full Moons crowded together is about equal to the size of the Fornax Dwarf.

Though it is extremely faint and thinly-populated, the galaxy is unusual in that it contains five conspicious globular clusters. The Fornax Dwarf is the only dwarf spheroidal galaxy in the Local Group to have any globulars and to find five of them in one is even more surprising. One of the globulars is **NGC 104**, which has a magnitude of 12.5 and can be picked up as a stellar object in a 6-inch (and probably a 4-inch in perfect skies). Three additional globulars (which lack NGC designations) are brighter than 13.6 magnitude. They might be visible in a small telescope, but you'll be wise to test your scope's limits on other objects first. Veteran observer Richard Wilds of Topeka, Kansas, has reported seeing a 13th magnitude star with his 2-inch refractor. But training your eye to perceive this isn't easy and it demands perfect observing conditions. There's hope with some experience and practice four of the five globulars may be in reach of a 3-inch telescope.

The Local Group

Object	R.A. (1950)	Dec.	Mag	Size	Type
IC 10	00h18m	+59°02′	12.4	2′ x 2′	I
NGC 147	00h30m	+48°11′	12.1	5′ x 3′	E
NGC 185	00h36m	+48°03′	10.3	2′ x 2′	E
NGC 205	00h38m	+41°27′	8.9	10′ x 5′	E5
M31	00h40m	+40°48′	4.3	160′ x 35′	Sb
M32	00h40m	+40°34′	9.1	3′ x 3′	E2
SMC	00h51m	−73°06′	1.5	216′ x 216′	I
Sculptor	00h58m	−33°57′	9.0	75′ x 75′	E
IC 1613	01h03m	+01°49′	11.5	14′ x 11′	I
M33	01h31m	+30°26′	5.7	65′ x 35′	Sc
Fornax	02h38m	−34°44′	9.0	20′ x 14′	E
LMC	05h24m	−69°50′	0.5	432′ x 432′	I
Leo I	10h06m	+12°32′	11.1	11′ x 8′	E4
Leo II	11h11m	+22°26′	12.4	15′ x 13′	E1
Ursa Minor	15h08m	+67°29′	11?	32′ x 21′	E
Draco	17h20m	+57°59′	11?	40′ x 25′	E
The Milky Way	17h42m	−28°59′	(Galactic center)		Sb?
NGC 6822	19h42m	−14°52′	9.2	16′ x 11′	I

One problem with determining how much you can see with a small scope is that most observers using them do not have a lot of experience. And as these owners pick up experience, they tend to move up to larger telescopes. The result is that the little scopes ("beginners' kid-stuff") are seldom tested to their limit. This means that anyone who sticks with a small instrument can frequently gain a keen understanding of the telescope's capabilities that few large telescope owners can ever hope to have with their instruments.

Why? Remember that the number of deep-sky objects visible grows at (dare I say it?) an astronomical rate as you increase the aperture. Any observer who uses his or her small telescope to the fullest will, over the course of years, scrutinize virtually every object that can be seen with it. In the same period of time, the big-scope owner can make only a slight dent in the zillions of objects visible in his scope — and will probably never see more than a fraction of the whole.

Alan Goldstein is Director of the National Deep Sky Observers Society, a Louisville, KY-based group of active observers. (For $6 sent to 3430 Bryan Way, Louisville, Ky 40220 you can get their newsletter *Betelgeuse*.) He is also a graduate student interested in terrestrial geology.

M31 photographed by David Healy some time after his first exposure. He used an 8-inch f/1.5 Schmidt camera, TP 2415 film, and a 30 minute exposure.

How to Polar Align Your Mounting for Photography

by David Healy

Why just *look* at them when you can *photograph* them? I carried this amateur photographer's bias with me when an old interest in astronomy revived a few years ago. So no sooner had I found the Andromeda Galaxy with my new Schmidt-Cassegrain telescope than I loaded my 35mm camera with high speed color film, attached it to the scope, and took a 20-minute time exposure.

The results, of course, were absolutely disastrous. In fact, the frames I squeezed off when loading the camera (subject: my foot, underexposed and out of focus) were considerably better than was my first shot of M31. It began to dawn on me that photography of deep-sky objects was not as easy as it seemed. I eventually learned, however, that anyone with a motor-driven equatorially-mounted telescope can produce presentable deep-sky photos if he or she can work out a sound photographic routine and eliminate the customary blunders.

No article of "how to" advice can prevent beginning astrophotographers from making all the customary blunders (as well as inventing some new ones) and wasting yards of perfectly good film in the process. This "goes with the territory." However, perhaps an article like this one can help shorten the startup period (during which no photos whatever turn out right) and prevent some young, aspiring Barnard or Hubble from becoming discouraged and turning instead to acupuncture or drag racing.

In my opinion, the rewards of deep-sky photography — compared with visual work — are worth the effort. Photography allows you to record information invisible through a telescope — faint stars, nebular and galactic detail, and color — and preserve it for a cloudy night.

None of this, however, was apparent on my first M31 photo: I didn't polar-align the telescope, guide the exposure, focus the camera, use the correct film, or expose long enough. And I had more problems: the focal ratio was too high, the telescope's corrector plate dewed up, the galaxy was too big to fit into the telescope's field of view, and I was shooting color from a light-polluted area. Nonetheless, M-31's nucleus did make a smudgy streak on my film after having traveled 2.2 million light years — I was hooked!

The streak M31's nucleus made on my film happened because the telescope was not properly polar-aligned: its drive did not exactly offset the rotation of the Earth because the Earth's axis and the telescope's polar axis were not aiming at the same point in the sky. I shall now describe how to polar-align a portable telescope — the first step in getting good deep-sky photos. Future articles will cover some of the topics suggested by the other blunders in my first deep-sky photo.

Coarse Alignment with the Finderscope

In only about five minutes, you can use your finderscope to achieve an alignment usually accurate enough to find objects with the scope's setting circles and accurate enough for much astrophotography. Primarily used with fork-mounted telescopes, it should be adaptable to other mountings as well. The first step is to make sure that your finder is collimated with your telescope; in other words that they are pointing in exactly the same direction. With the drive on, center a bright star in the telescope's eyepiece and adjust the finder until the same star is at the intersection of the finder's crosshairs. Then check again to make sure the star is still centered in the telescope

eyepiece.

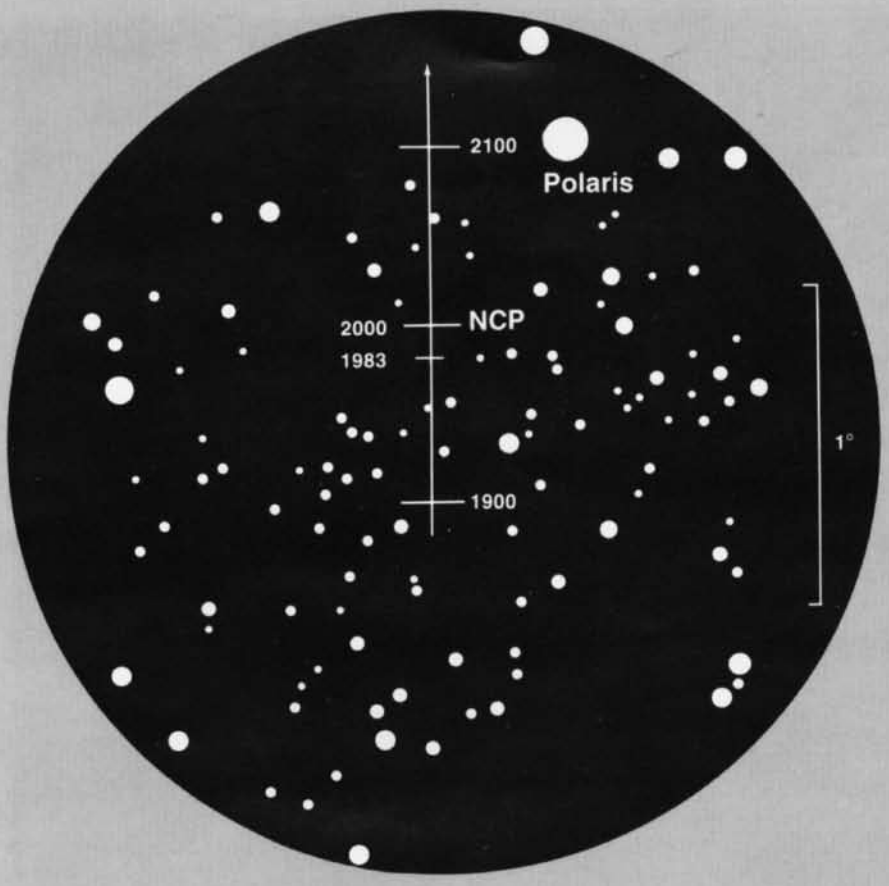
Next, orient the finder's crosshairs so that they parallel the declination and right ascension axes of the telescope. To check this, center a bright star on the finder's crosshairs and move the telescope in declination (north/south) or in right ascension (east/west). The star should travel along the finder's crosshairs as you move the telescope. If not, rotate the finderscope in its mounting. Then you may have to recheck the collimation to make sure the finder and telescope are still in alignment.

The next task is to determine your finder's field of view. With the telescope drive off, let a star on or near the celestial equator drift across the center of the finder's field of view, bisecting it. The number of minutes this takes, divided by four, is the finder's approximate field of view in degrees. Many finders have 4° fields, as indicated by a star-drift time of about 16 minutes. You'll need to know the finder's field to guesstimate the 0.8° distance between Polaris — the pole star — and the celestial pole itself.

At this point we know our finder's field and know that the pole is 0.8° from the pole star, but we don't know which direction the pole is from Polaris. Fortunately there is an imaginary line in the sky that intersects both the pole and the pole star. The line runs from Eta (η) Ursae Majoris, the star at the end of the Big Dipper's handle, through the celestial pole, through the pole star, and ends at Epsilon (ε) Casseopeiae, the northeasternmost star in the "W" of Casseopeia. It should be easy to remember, then, that the pole itself is 0.8° from Polaris, in the direction of the Big Dipper.

The next step with a fork-mounted telescope is to turn the scope until the declination circle reads 90° and the scope is pointing more or less in the direction of the pole star. Next, turn the telescope in right ascension until the declination axis of the telescope is perpendicular to the imagingary Dipper-pole-Polaris-Casseopeia line in the sky. This is accomplished by sighting from the rear (south) end of the telescope tube. In other words, one of the finder's crosshairs should track along the imaginary line in the sky.

Next, with the telescope's dec. and R.A. axes locked, move the scope's base or mounting in altitude and azimuth (up/down, right/left, respectively) until Polaris lies 0.8° from the center of the finder's field along the crosshair that tracks the imaginary line in the sky. Remember that most finderscopes invert the view, so if Polaris happens to be to the right of the pole in the sky, it should lie 0.8° to the left of the center of the finder's field. This procedure may sound complicated, but some "hands on" practice should enable you to polar-align accurately enough for many purposes in less time than it takes to read about it.



Fine Polar Alignment

But you shouldn't stop here. You'll want a more precise alignment because it will allow you to find dim objects promptly with setting circles and it minimizes — or even eliminates — the necessity for guiding corrections in declination, increasing the odds for a better photo. Once you've achieved coarse alignment, you can more precisely "zero in" on the pole by one of two methods: first, see the detailed map with this article and place the scope centered on the exact north celestial pole. Second, there is a trial-and-error method originated, I believe, by Robert Provin, Brad Wallis, and Robert Little.

With an illuminated-reticle guiding eyepiece in your telescope or guidescope, point the scope at a star near the celestial equator and near the meridian. Orient the reticle crosshairs so that moving the telescope in R.A. slews the star along a crosshair. Recenter the star and let the telescope track for, say, five minutes. If the star drifts *north*, your scope's polar axis is pointed too far to the *west*. If the star drifts *south*, the polar axis is too far *east*. (Ignore drift in right ascension.) Move the telescope's base or mounting in the required direction and repeat the procedure until the star's drift is eliminated. First attempts will be clumsy — don't be discouraged.

Next, point the telescope at a star near the equator and near the eastern horizon, and center it in the reticle crosshairs as before. Again let the scope run for about five minutes. If the star drifts *north* in your eyepiece, the scope's polar axis is *too high*. If it drifts *south*, the axis is *too low*. Move the scope's axis in the required direction, and repeat the procedure until you've eliminated the drift. Now your scope should be precisely polar-aligned. It's a good idea to re-check using the first method at this point, just to be safe.

This method can be time-consuming, but I've found that unless I'm unusually clumsy I can "drift-align" with time to spare between when the stars first appear and the end of astronomical twilight, when I want to begin photography. If you leave your scope assembled for any length of time, one drift alignment session suffices for the whole period.

Remember that this whole procedure — once practiced — is much less complicated than it sounds. Practice patiently and carefully, because polar alignment is so important in astrophotography that once it is done properly, the rest is downhill!

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Viewing Galaxies in Triangulum

by Brian Skiff

A small slice of sky wedged between Andromeda and Aries, **Triangulum** is a constellation rich in galaxies. It lies sufficiently far enough away from the plane of the Milky Way that Galactic objects don't in the way, and we have a clear view of external systems of stars. Indeed *Burnham's Celestial Handbook*, a pretty reliable listing of bright deep-sky objects, lists 8 galaxies and no other objects in the constellation.

The brightest and best object in Triangulum is **M33** (NGC 598), a magnitude 5.7 SA(s)cd-type spiral sometimes called the "Pinwheel Galaxy." According to Zwicky, 16 NGC or IC numbers — NGC 598 included — apply to this galaxy. M33's center lies at 01h31.0m, +30°24′ (1950); its total area measures an imposing 65′x35′ across. This galaxy is perhaps the second finest in the sky, and is a magnificently complex object, being a close spiral presented almost face-on. Many tiny details show up in large backyard telescopes, including stellar associations, HII regions, star clouds, etc. The photo on page 20 identifies a number of features in M33, many of which you can observe with your scope. Objects indicated with an "S" are foreground stars within the Milky Way. The brightest star in M33 itself is Humphreys and Sandage #324, located in their Association #67 (north of the nucleus), at magnitude 15.2 (visible, perhaps, in 12-inch reflectors under great conditions). But most stars belonging to M33 are fainter than visual magnitude 17.0.

Although M33 has a low surface brightness due to its large size and face-on angle, it is faintly visible to unaided eyes on dark clear nights. In Flagstaff I see it as a tiny hazy spot about 10′ across — not as large as the moon's 30′ diameter. A 2.4-inch refractor at low power (25x) shows a large bright oval elongated in p.a. 30°. The core shows only as a slight broad condensation extending more directly north-south, due to the brighter inner arms of the galaxy. At higher powers the core dominates the view. An 8th magnitude star (BD+29°256) lies within the southern perimeter of the galaxy; a 9th magnitude star is off a bit to the west,

NGC 925 K.A. Brownlee

and a magnitude 9.5 star shows up on the north end. With a 6-inch aperture instrument the bright HII region **NGC 604** is clear, and many stars are visible over the face of the galaxy.

I've studied this galaxy extensively with a 10-inch reflector, and the limiting magnitude at 190x was close to 15.0. At this magnification NGC 604 is a very bright object (magnitude 10.5) 12′ northeast of the nucleus, and appears about 30″ x 20″ in diameter in p.a. 120°. Two faint stars are involved on either side, the one on the northwest being a bit brighter. A small dark spot is visible between the stars. Southeast of 604 is a magnitude 10.5 star, and just southeast of this is **Association 85**. This group was faintly visible as a magnitude 13.8 mottled haze.

At the north end of the galaxy, **Association 137** faintly shows in the 10-incher. Just as in photographs, it is elongated and has a faint star at the tip of the "S" — actually this is an entire cluster that includes two 16th magnitude stars. The nearby pair of stars (13, 13; 10″; 140°) resolved at 125x, and should be visible in a 6-inch scope. The HII region just north of the pair didn't show up, perhaps due to the glare from the pair and the nearby magnitude 9.5 star.

Moving westward along the spiral arm from star G, there is a bright smudge at **Association 75**, which has a magnitude 13.5 star on its southeast edge. At **Association 67** (which contains the star 324) I see a mottled haze, probably the combined light of several stars including 324. **Association 34**, just north of the star Q8, is visible as a faint star-like spot.

Northwest of the nucleus is **Association 62**. It appears nebulous, about 15″ across, and about the same magnitude as star S6 to its north. Farther southwest is a brighter blob, **Association 59**, directly west of the nucleus. Isolated between spiral arms, this object is the most conspicuous region other than 604 (and the nucleus, of course). It appears elongated in a southeast-northwest orientation, due to a "star" on its southeast edge, which the photo shows to be a bright cluster. The large HII ring in **Association 27** appeared as a star-like spot surrounded by very little haze of low surface brightness.

The large object designated **Association 131**, involving stars SJ30 and A4, shows little haze perhaps again

due to the glare from the two stars, which were clear at 125x. I could not see **Association 22**, located between stars SJ30 and TJ. The bright associations south of the core didn't show themselves clearly, but appeared as clumpy bright areas. I saw faint mottling around **Association 4** and **Association 5**, but I just needed a little more aperture! Perhaps some of you large Dobsonian owners can pick these objects out of the general haze.

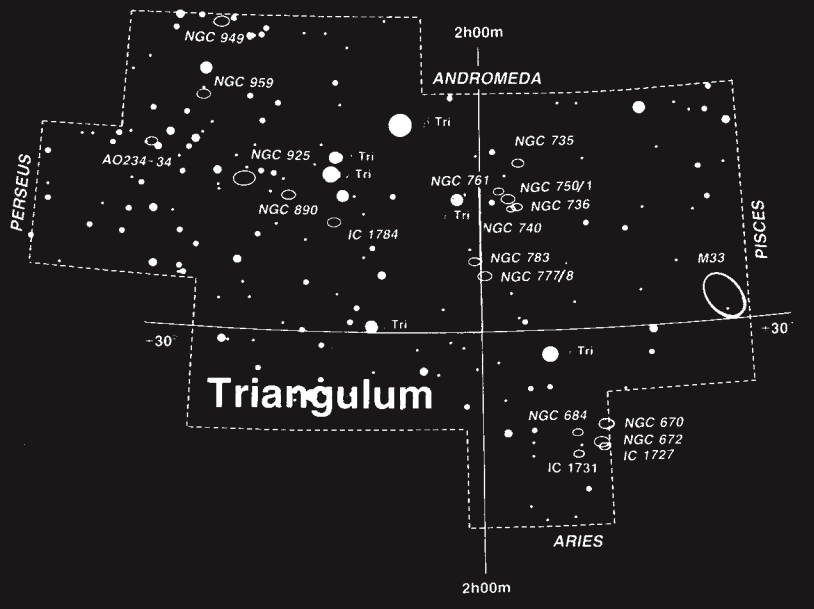
Well southeast of the nucleus (12′) is a magnitude 11.8 star, just north of which lie two more associations. **Association 101** is conspicuous visually, a large low surface brightness feature with a roughly circular outline. **Association 100** is clearly elongated in p.a. 45°, and its southeast flank is sharply defined. I could not, however, see the bright spot (a nebulous cluster) which appears near the center of the feature on the photo. (The large spot near — just left — of the "101" label in the photo is a flaw on the original plate.)

The two broad associations south of +29°256 — **Association 110** and **Association 112** — are difficult to view because of the star. West of the star, **Association 116** is visible as a faint spot. To the north, **Association 127** shows an elongated form with a 13th magnitude star in its center. To the northwest, **Association 128** shows up well, although faintly. It doesn't appear as "starry" as others do, and is about 15″ in diameter. **Association 14**, though bright, is barely discernable from the background. I failed to see the brightest globular cluster in M33, Kron and Mayall's "c", located 22′ southeast of the center of the galaxy.

In tackling M33 at the eyepiece, try to think of each feature as a separate object, like a faint galaxy (which they resemble) or cluster (which they are). Also, though you should use high powers on this faint stuff (20x to 25x per inch of telescope aperture), pause occasionally to switch to low powers. This allows you to keep track of your location in the galaxy and get a feeling of the overall layout of the spiral.

You don't need a large scope to enjoy viewing M33. I propose some tests for readers: can you see the bright gas cloud NGC 604 in a 2.4-inch or 3-inch scope? How many associations can you detect with a 6-inch or 8-inch instrument? Can some assiduous observer do a more thorough job surveying the stars visible over the face of the galaxy? Observers who come up with interesting results should contact the Editor.

The photo on page 20 was taken on 23 September 1965 with the 1.5-meter f/9.6 astrometric reflector at the U.S. Naval Observatory in Flagstaff. The original 8″ x 10″ 103a-O plate was exposed for 60 minutes and has a scale of 7.33′ / inch. North is up and east to the left. Associations are marked with numbers — stars with numbers and/or letters.

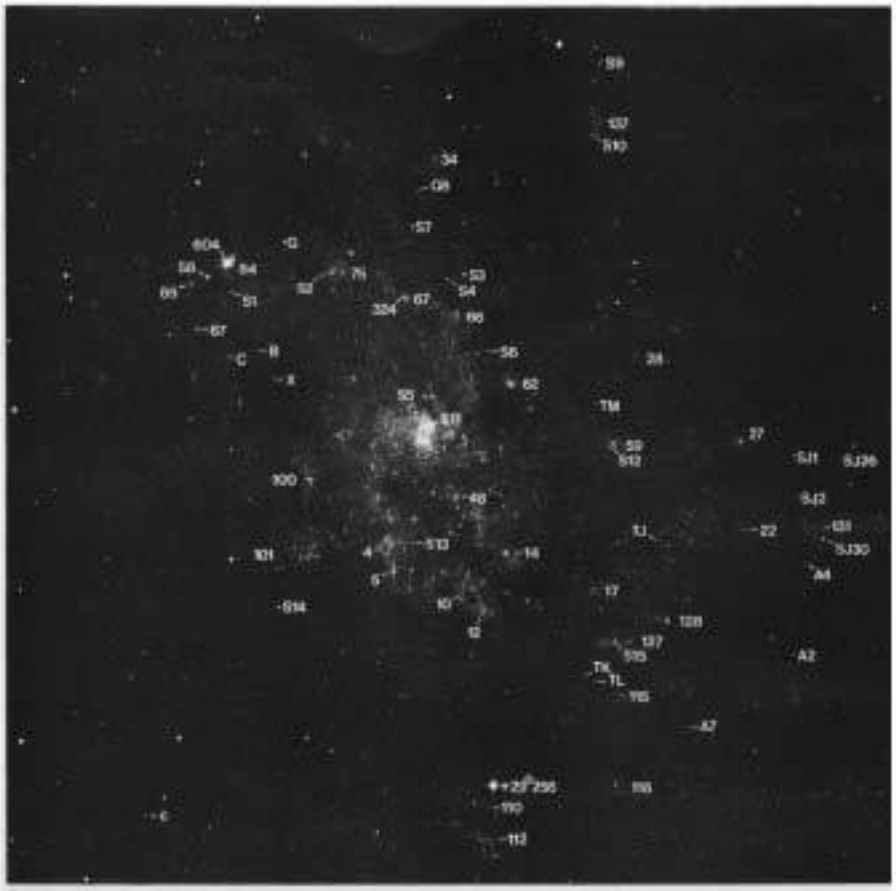


Object	R.A. (1950)	Dec.	Size	Mag.B	Sfc.	Type
M33	01h31.1m	+30°24′	65.0′ x 35.0′	6.3	14.6	SA(s)cd
NGC 670	01h44.6m	+27°38′	2.5′ x 1.1′	13.0	14.0	SAO
IC 1727	01h44.7m	+27°05′	6.2′ x 2.9′	12.1	15.1	SB(s)dm
NGC 672	01h45.1m	+27°11′	6.6′ x 2.7′	11.3	14.3	SB(s)d
IC 1731	01h47.4m	+26°57′	1.7′ x 1.1′	14.2z	—	SAB(s)c
NGC 684	01h47.4m	+27°24′	3.9′ x 0.9′	13.2z	—	Sb sp
NGC 735	01h53.7m	+33°56′	2.0′ x 1.0′	13.9z	—	Sb
NGC 736	01h53.8m	+32°48′	2.0′ x 1.9′	13.2	14.5	(R′)SAO–:
NGC 740	01h54.0m	+32°46′	1.7′ x 0.5′	—	—	SBp?
NGC 750	01h54.6m	+32°58′	1.6′ x 1.3′	13.2	14.0	E pec
NGC 750+1	01h54.6m	+32°58′	2.9′ x 2.0′	12.4	14.3	—
NGC 751	01h54.6m	+32°58′	1.3′ x 1.3′	13.5	14.1	E pec
NGC 761	01h54.9m	+33°08′	1.6′ x 0.6′	14.5z	—	SBab?
NGC 777	01h57.4m	+31°11′	3.0′ x 2.5′	12.4	14.5	E1
NGC 778	01h57.4m	+31°03′	—	14.2z	—	—
NGC 783	01h58.2m	+31°38′	1.8′ x 1.6′	12.8z	—	Sc
IC 1784	02h13.3m	+32°25′	1.6′ x 1.0′	14.1	14.1	(SA)rs)bcp
NGC 890	02h19.0m	+33°02′	2.9′ x 1.9′	12.3	14.0	SAB(r)O–?
NGC 925	02h24.3m	+33°21′	9.8′ x 6.0′	10.6	14.9	SAB(s)d
NGC 949	02h27.3m	+36°55′	2.8′ x 1.7′	12.5	14.1	SA(rs)b:?
NGC 959	02h29.3m	+35°17′	2.2′ x 1.4′	12.5z	—	Sdm:
AO234+34	02h34.6m	+34°13′	1.5′ x 1.0′	14.2	14.5	(R)SB(s)a:

All galaxy data are from the *Second Reference Catalogue of Bright Galaxies*, de Vaucouleurs, et al., 1976. Magnitudes are in the B system except those marked with "z", which are blue photographic magnitudes from Zwicky.

The second group of objects lies in a part of the constellation's southern border close to Pisces. The brightest object in this group is **NGC 672**, an 11th magnitude large galaxy lying 13′ northwest of a small diamond of 10th magnitude stars. You might be able to pick out this galaxy with a 2.4-inch or 3-inch refractor, but you'll need a 6-incher to see it as an oval haze, elongated east-west. A 13.5 magnitude star is visible on the northwest flank. In a 10-inch scope the low surface brightness halo measures 4′ x 1.5′ in p.a. 80°. The outline is fatter on the west and tapers to a point at the east end, where there is another magnitude 13.5 star. Using averted vision, a faint mottled structure shows along the negligibly condensed central bar.

Just 9′ southwest of NGC 672 is another large galaxy with which it may be interacting. **IC 1727** has a low surface brightness, and even though its total magnitude is 12.1, I couldn't see it in a 6-inch telescope. In a 10-inch instrument, however, it appears as a



U.S. Naval Observatory

Stellar Associations and features in M33.

vague haze about 3′ x 1.5′ across, elongated in p.a. 135°. I saw no central condensation, but could see some mottled nebulosity. Still in the same low power field is **NGC 670**, a 13th magnitude SA0 type galaxy. In 6-inches' aperture it is pretty faint and appears stellar, forming a triangle with two 10th magnitude stars. A 10-incher at high power — about 200x — shows that the tiny lenticular halo is 0.7′ x 0.2′ across in p.a. 165°. The narrow, slightly brighter core contains a stellar nucleus of about magnitude 14.5 which I saw just south of center, though photographs indicate a perfect symmetry.

A similar object is **NGC 684**, which appears as a 13th magnitude "star" in a 6-inch telescope. A magnitude 12.5 star is visible on the east side. A 10-inch telescope reveals a magnitude 13.5 star on the east edge of the galaxy. The two stars tend to get in the way, but I estimate the galaxy's diameter at 40″. A triple star lies 5′ southwest; the approximate magnitudes and separations going east to west are: 12, 13.5, 12; 12″ and 30″.

Another group of galaxies lies to the north between Alpha (α) and Epsilon (ε) Trianguli. Epsilon Tri is not an easy double star (5.4, 11.4; 4.2″, 118°), but is an easy offset star for several galaxies. A little more than a degree west from ε are **NGC 750** and **NGC 751**, which together form an interacting pair of galaxies in a common envelope. The two galaxies have a fairly high total brightness, and thus are visible at 65x in 6-incher. At higher powers this aperture shows a beady appearance to the nebulosity, which is elongated north-south. A 10-inch scope shows two bright nuclei 0.4′ apart: the one on the north (750) is substellar and glows at magnitude 13.2, while the southern one (751) is stellar and a little dimmer at magnitude 13.5. The enveloping region measures 1½′ x 1′ overall with a circular bulge on the north side like a draftsman's "figure 8." The nuclei fade suddenly to their diffuse merged halos. A few arcminutes east is the pair ADS 1562 (8.9, 9.2; 1.5″, 230°) which is easy prey for a 10-inch telescope.

Not far northeast of the interacting galaxies is **NGC 761**, which I could not see in a 6-inch scope. With a 10-incher it shows only at 190x, and is located on the southwest side of a triangle of 13th magnitude stars. It appears as a small spot with a stellar nucleus elongated in p.a. 150°. About a degree north of NGC 761 is the faint galaxy **NGC 735**, visible in a 10-incher as a small lenticular halo 0.9′ x 0.3′ across, elongated southeast-northwest. There is no central brightening, but a magnitude 13.5 star lies in the northwest tip of the galaxy.

Only 10′ southwest of the pair of interacting galaxies is **NGC 736**, a 13th magnitude object. With a 6-inch scope I was barely able to see it; a 10-incher at 190x showed it to be about as bright as NGC 750. A curved line of three very faint stars on the north side interfere slightly with observing this galaxy. A fainter companion — **NGC 740** — lies a few arcminutes southeast. Farther south is **NGC 783**, at 13th magnitude a fairly faint object for 6-inches' aperture but visible at 125x. The small spot is bracketed by stars on its west-northwest and south-southeast sides. In a 10-inch telescope the galaxy is roughly circular, 1.25″ in diameter, and smoothly textured with perhaps a very slight central brightening. The west-northwestern star shines at magnitude 12.5 and appears to be just outside the halo; the other bracketing star is a 12th magnitude object.

NGC 777, a magnitude 12.5 object, is also visible in a 6-incher at 125x — it is pretty faint, but under good conditions you'll note a stellar nucleus. In a 10-inch scope the galaxy spans 1′ across with a small, somewhat brighter core and stellar nucleus. The halo is very diffuse, of low surface brightness and without a definite edge; but it seems slightly elongated in a southeast-northwest orientation. A faint companion, **NGC 778**, is not difficult to see in a 10-incher — it appears as a spot 20″ across with a bright, nearly stellar nucleus.

Heading east, several more galaxies are scattered across the constellation. **IC 1784** has a fairly low surface brightness, and showed up best at 125x in the 10-inch scope. The object is elongated in p.a. 90° and the western end seems fatter, more rounded. A threshold magnitude star is just off the eastern tip while a mottled haze occupies the western end. **NGC 890** is a fairly easy object for 6-inches' aperture. The small halo is faintly elongated in about p.a. 60° and a conspicuous stellar nucleus is visible. In the 10-incher it measures 1.25′ x 0.75′ across with a small, nearly circular core and stellar nucleus. Using averted vision I suspected faint extensions in the halo, reaching out to 2′ x 1′.

To the northeast is a large 10th magnitude galaxy designated **NGC 925**, which is faintly visible in a 2.4-inch scope as a long, thin spike with pointed tips over a small round core. The galaxy appears to be elongated north-south because stars lie on opposite sides of the core: they are resolved in large apertures. With a 6-incher NGC 925 seems translucent with no positive condensation. A 10th magnitude star lies to the south, and magnitude 12.5 and 13 stars show up on the northwest side of the core. The large, diffuse, low surface brightness halo contains a weak central bar at about p.a. 100°. In 10-inch scopes the bar extends to 2′ x 0.5′ across and exhibits conspicuous mottling. At least eight stars appear in the 6′ x 4′ nebulosity, which doesn't

quite extend to the 10th magnitude star to the south. Some vague light and dark areas show up in the halo, but most of the details are in the bar. Compare the sketch and photo in this article — you'll see that one of the "stars" on the galaxy's edge is actually an extended stellar association and HII region.

Near the variable R Trianguli is a faint anonymous galaxy known simply as **A0234+34**. Visible in a 10-incher at 125x, the featureless circular spot appears just 40″ across. At the northern border of Triangulum are two more moderately bright objects — 12.5 magnitude **NGC 959** is visible, albeit faintly, in a 6-inch telescope. A 10-inch telescope shows a bright galaxy of moderately high surface brightness with a fairly definite edge. The halo is 1.3′ x 1′ in p.a. 65°, and some indefinite mottling appears on the central two-thirds of the object. Somewhat brighter is **NGC 949**: a 6-inch instrument shows it to be an obvious streak, 1.0′ x 0.75′ across, elongated southeast-northwest, with a brighter nearly stellar center. A 10-inch scope at 190x shows it as 1.5′ x 1′ in diameter in p.a. 140°, the core bulging slightly from the lenticular halo. The core is oval in shape, displaying a slightly grainy texture and stellar nucleus. A 14th magnitude star lies along the southwest flank of the galaxy at p.a. 165° from the nucleus. In a 12-inch instrument the galaxy grows to 2.5′ x 0.75′. The broad core shows a thin lengthwise brightening and the halo fades more abruptly on the southwest flank.

There are at least 22 galaxies in Triangulum that can be observed with moderate-size backyard telescopes, including M33, one of the finest galaxies in any part of the sky. Fall is a time of crisp, clear skies, a time to get out and see what you can of these pinwheel stellar systems. Some of them may be faint fuzzy elongated patches in your eyepiece, but you know that luminous grey-greenish band of light represents energy from a hundred billion stars and billions of worlds.

If you've done your homework you'll take a red-filtered flashlight along with your star chart and copy of DSM. If you don't already, take a sketchpad with circles representing the telescope's field of view. Try your hand at sketching the star positions and nebulosity you see. It isn't as difficult as you might think, and is very rewarding and exciting (see ASTRONOMY, February 1983). If you're happy with the way your sketches come out, let DSM have a copy: we'll publish a section of them if the response is large enough. We'll also look for astrophotos of these objects made by DSM readers. Now get out there and observe!

421 West Aspen
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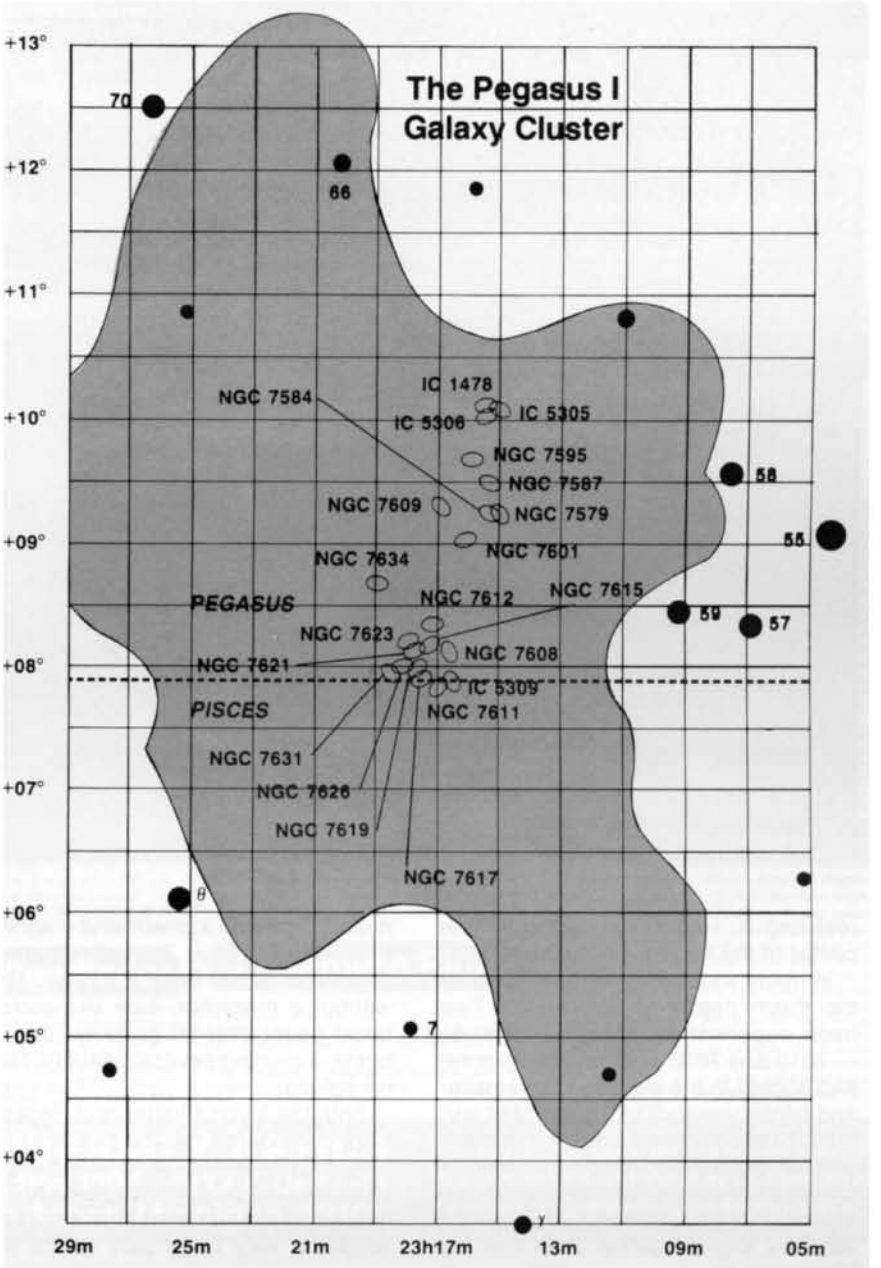
Observing the Pegasus I Cluster

by Jim Meketa

My observing site on the south coast of Martha's Vineyard Island in Massachusetts was surrounded by New England pitch pines, limiting my field of view of within 40° of the zenith. The moonless August nights had been clear and very dark, although marred by heavy dew and occasional mosquitos. I could easily see 6th magnitude stars, and the Milky Way was a rich mass of star clouds, dark rifts, and clusters as it moved behind the western pine curtain. I had been searching for galaxies in the belly of Pegasus for two hours, and was ready to call it a night. This area is rich in galaxies and clusters of galaxies, but most of them are very distant and faint. On his *Sky Atlas 2000.0* Wil Tirion plots only 18 galaxies in this enormous expanse of sky, 60° x 20°, even though none of it is obscured by the Milky Way.

Before packing up, I decided to take a quick look at a pair of NGC galaxies near the faint trapezoid of stars formed by 55, 57, 58 and 59 Pegasi. All four stars in the trapezoid were easily visible to my naked eye, so I had no trouble centering the proper field in my 18-inch f/4.5 Newtonian. But instead of two galaxies I saw seven, all in nearly the same eyepiece field! The two brightest galaxies were the ones plotted in the *Sky Atlas 2000.0*, **NGC 7619** and **NGC 7626**, separated by about 8 arc minutes. Surrounding them on all sides were 5 more galaxies, considerably fainter but easily visible nevertheless. Without



Pegasus I Members

NGC or IC	R.A. (1950)	Dec.	Mag.	Comments
7619	23h17.7m	+ 7°56′	12.7	Bright, condensed, nearly round, stellar nucleus.
7626	23h18.2m	+7°57′	12.8	Virtually identical to 7619, 8′ east.
7617	23h17.6m	+7°54′	15.1	Large faint patch very close (3′) to 7619.
7611	23h17.1m	+7°47′	13.6	Fairly bright, oval, stellar nucleus, 7 mag red star Sf. Same field as 7619.
I.5309	23h16.6m	+7°50′	15.0	Small, very faint, stellar nucleus. Near 7611.
7631	23h18.8m	+7°56′	13.8	Small, oval, very diffuse, slightly brighter middle, hint of a stellar nucleus. 10.5′ East of 7626.
7623	23h18.0m	+8°07′	13.9	Fairly bright, round, condensed nuclear region. About 11′ N of 7619/7626, forming a long triangle with them.
7621	23h17.8m	+8°04′	15.6	Extremely faint, small glow surrounding a stellar nucleus. Next to 7623.
7615	23h17.4m	+8°08′	15.3	Small, round, very faint. No nucleus.
7608	23h16.7m	+8°04′	15.2	Large, faint oval, very low surface brightness. Wide double star just Sp.
7612	23h17.2m	+8°17°	14.3	Large, fairly bright, condensed middle, stellar nucleus. A 15.7 mag galaxy is about 1.5′ f but I did not notice it.
7634	23h19.1m	+8°36′	13.7	Fairly bright, distinctly elongated, faint star involved.
7601	23h16.3m	+8°58′	14.7	Medium size, very fiant, stellar nucleus.
7609	23h17.0m	+9°13′	15.3	Very round, faint, featureless. Faint stars involved. On the *Palomar Sky Survey*, this is clearly a double galaxy, with faint connecitng bridges and several very faint attendant galaxies.
7579	23h15.1m	+9°09′	15.4	Almost stellar, extremely faint, featureless. Very difficult.
7584	23h15.4m	+9°09′	15.3	Very small, extremely faint, similar to nearby 7579.
7587	23h15.5m	+9°25′	14.9	Very faint oval, slightly brighter middle, no stellar nucleus.
7595	23h15.9m	+9°38′		A small, round, faint patch, faint star p, very faint star just S. Missed by Zwicky, but clearly visible at the edge of the Palomar print.
I.1478	23h15.7m	+10°02′	15.3	Fairly large, oval, faint, no nuclear brightening.
I.5305	23h15.6m	+10°02′	15.4	Small, round, faint glow surrounding a stellar nucleus. Two faint stars in a line S.
I.5306	23h15.6m	+9°58′	15.6	An extremely faint, small round patch. Actually a double galaxy on the *Palomar Sky Survey*.

realizing it, I had chanced upon the center of the Pegasus I galaxy cluster.

In many ways, Pegasus I resembles the much nearer Virgo Cluster. Two huge, superluminous elliptical galaxies — 7619 and 7626 — dominate its core, and appear in the eyepiece like smaller and fainter versions of Virgo's M84 and M86. Stretching away on all sides are smaller galaxies beyond counting. On the negative-image *Palomar Sky Survey* print the area around 7619/7626 appears slightly darker than the sky nearby, and with a small hand magnifier I could see why. The sky there is peppered with faint galaxies that, without a magnifier, look like stars. I could count over 30 galaxies in a 45′ circle, including several beautiful face-on spirals.

Both the Virgo Cluster and Pegasus I are considered nearby clusters. The Virgo Cluster contains over 2,500 galaxies, but is only about 70 million light-years distant, and hence spreads across a very large part of the sky. Pegasus I contains about 1,000 known members, but at 230 million light-years' distance, it covers an area no larger than 6° by 8°.

Being over three times more distant, we would expect the Pegasus I galaxies to be, on average, about 11 times or 2.6 magnitudes fainter than those in Virgo. And indeed they are. The two brightest members, 7619 and 7626, are only 12.7 and 12.8 magnitude respectively. M84 and M86, on the other hand, are both 10.5. But despite their enormous distance, an observer with access to an 18-inch or larger telescope and perfect skies should be able to locate up to 100 Pegasus I members. Most of the galaxies, of course, would be very small objects no brighter than 15th magnitude.

I was able to find 21 members in about an hour, using as a reference the now out-of-print *SAO Star Atlas*. My work would have been much easier if I had had available at the telescope the Zwicky charts or the appropriate print from the *Sky Survey*.

In the table, I have listed the 21 galaxies I was able to detect near the center of the cluster. They range from bright and easy to extremely difficult. I believe you'll need a scope of at least 12-inches' aperture and perfect conditions to see them all.

There are dozens of other galaxies in this cluster visible to large amateur telescopes, some as bright as 13th magnitude. But to find and identify any but the brightest you'll have to seek out several of the following refererences: *Catalog of Galaxies and Clusters of Galaxies*, Zwicky, et al., Cal Tech, 1961-68, in 6 volumes; *Second Reference Catalog of Bright Galaxies*, de Vaucouleurs et al., Univ. of Texas Press, 1976; *Revised New General Catalog of Nonstellar Astronomical Objects*, Sulentic and Tifft, Univ. of Arizona Press, 1973; *Palomar Observatory/National Geographic Society Sky Survey*, Cal Tech Bookstore, 1960; *SAO Star Atlas of Reference Stars and Non-Stellar Objects*, MIT Press, 1969. You'll be able to find most of these in college libraries, and you can order individual *Palomar Sky Survey* prints relatively cheaply from the Cal Tech Book Store (1-51 San Pasqual St., Pasadena, CA 91125).

Remember as you look at these distant galaxies that the light you see left them just as the Paleozoic era on Earth was ending. The great coal and oil deposits of the Carboniferous and Permian periods had been laid down, and the trilobites that make such beautiful fossils today were dying out. But the age of the great dinosaurs was still 50 million years in the future.

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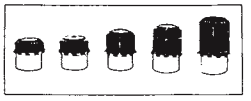

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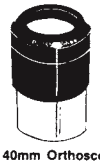

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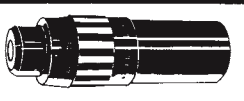

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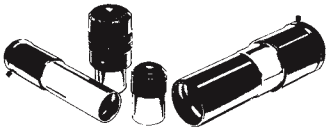

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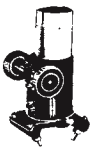

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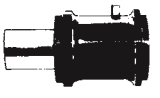

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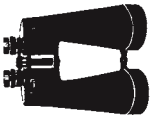

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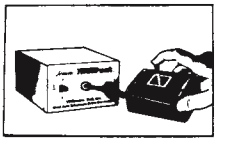

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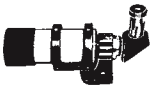

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The Finest Double Stars of Autumn

by Glenn F. Chaple, Jr.

Autumn is the season when cold air masses from Canada sweep south into the United States, driving before them the warm, damp air from the Gulf of Mexico that dominates summer. Within 24 hours after a cold front passes, you can expect skies that are clear *and* steady — optimum conditions for all kinds of astronomical activities. Some of my most memorable and productive observing sessions occurred in the wake of an autumn cold front.

The autumn constellations, dominated by the "Great Square" of Pegasus, are deceptively barren-looking. But as any good telescope will show, Pegasus and company are chock-full of celestial treats — especially double stars.

This is the fourth and final installment in a series that highlights the 100 finest double and multiple stars visible from northern latitudes. From the area of sky between 20h eastward to 2h in R.A. and north of −40° declination, I've rounded up 25 of the best that grace our autumn evenings. Once again, variety is the keynote. Binocular and RFT owners will enjoy wide pairs like α Capricorni, while those of you who observe with small scopes can marvel at the beauty of γ Delphini and γ Arietis. Own a big scope? Then try your luck with the tight pair μ Cygni. Above all, get out and enjoy those superb autumn nights!

Omicron^1 (o^1) Cygni (1950) 20h 12.0m, +46° 35′ (magnitudes 4.0, 7.1, 5.1; separations 106.8″, 337.8″; position angles 173°, 1926; 323°, 1926). Located 5° west of Deneb, o^1 Cyg is a striking triple in binoculars and RFTs. The main star is golden yellow and the companions blue.

Alpha^{1,2} ($\alpha^{1,2}$) Capricorni 20h 14.9m, −12° 40′ (mags. 4.6, 9.0, 3.7, 9.5; seps. 45.4″, 154.6″; p.a. 221°, 1932, 156°, 1909). The magnitude 3.7 and 4.6 stars form a naked eye pair separated by 376″ in p.a. 291°. A 3-inch scope handily shows the 9th magnitude partners. Look 2½° south and slightly east for the wide yellow and blue double β Capricorni (mags. 3.1, 6.0; sep. 205.0″; p.a. 267°). If you have a pair of binoculars, this is a fine region to sweep them through.

Gamma (γ) Delphini 20h 44.4m, +15° 57′ (mags 4.5, 5.5; sep. 10.0″, p.a. 268°, 1957). Located in the Dolphin's "snout," γ Del is one of the finest double stars for small telescopes. Can you detect the subtle yellow and blue hues that some observers report seeing? In the same field, 15′ to the southwest, is the delicate little pair Σ2725 (mags. 7.5, 8.2; sep. 5.7″; p.a. 9°).

61 Cygni 21h 0.4m, +38° 28′ (mags 5.6, 6.3; sep. 29.0″; p.a. 146°, 1980). There's more to this star than just the pretty golden yellow of its components. 61 Cyg is historically important as the first star whose distance was accurately determined (by Friederich Bessel in 1838). Its current value of 11.1 light-years' distance places it among the nearest of the naked-eye stars. 61 Cyg forms a rough parallelogram with α, γ, and ε Cyg.

Beta (β) Cephei 21h 28.0m, +70° 20′ (mags 3.3, 8.0; sep. 13.6″; p.a. 250°, 1954). Despite the difference in magnitudes, this pair is rather easy for small instruments. Use 50x to 75x.

Σ2816 Cephei 21h 37.4m, +57° 16′ (mags 5.8, 7.7, 7.8; seps. 11.7″, 19.9″; p.a. 121°, 1958; 339°, 1958). In the same field as this star and just 10′ eastward is the double star Σ2819 (mags. 7.5, 8.5; sep. 12.4″; p.a. 57°). Together, Σ2816 and Σ2819 make for a grand sight.

Epsilon (ε) Pegasi 21h 41.7m, +9° 39″ (mags 2.3, 8.5; sep. 142.5″; p.a. 320°, 1913). These two stars form an optical, or line-of-sight, double. What makes them so intriguing is the apparent pendulum-like motion of the fainter star that occurs when the telescope is gently rocked in a direction perpendicular to a line joining both. The effect is quite startling!

Mu^{1,2} ($\mu^{1,2}$) Cygni 21h 41.9m, +28° 31′ (mags 4.7, 6.1; sep. 1.8″, p.a. 298°, 1980). A binary pair with an estimated orbital period of five centuries, $\mu^{1,2}$ Cyg is becoming increasingly harder to resolve as it closes toward its minimum separation of just 0.8″ in the year 2017.

Xi (ξ) Cephei 22h 2.2m, +64° 23′ (mags 4.6, 6.5; sep. 7.5″; p.a. 278°, 1952). There's something about the magnitude difference and closeness of this pair that makes it especially appealing.

Zeta (ζ) Aquarii 22h 26.2m, -0° 17′ (mags 4.4, 4.6; sep. 1.8″; p.a. 226°, 1980). These beautiful twins form a binary system whose period is still uncertain. The two were 4.5″ apart when measured by William Herschel two centuries ago. After closing to just under 1.8″ in 1977, they are slowly beginning to separate once again. You can split this pair with a 3-inch scope if you use at least 100x and observe when skies are steady.

Delta (δ) Cephei 22h 27.3m, +58° 10′ (mags var, 6.5; sep. 40.7″, p.a. 192°, 1961). Use low power — 20x to 30x — on this yellow and blue pair. The main star is the prototype Cepheid variable, and pulsates regularly in a 5.4-day cycle, varying in brightness between magnitudes 3.6 and 4.3.

8 Lacertae 22h 33.6m, +39° 23′ (mags 5.8, 6.6, 10.5, 9.5; seps 22.4″, 47.8″, 81.1″; p.a. 186°, 1958; 169°, 1956; 145°, 1956). You may have difficulty finding this multiple star, as it lies in a rather barren field.

Sigma (σ) Cassiopeiae 23h 56.4m, +55° 29′ (mags 5.0, 7.1; sep. 3.0″; p.a. 326°, 1958). The two-magnitude difference in brightness between these two makes them difficult to resolve in small scopes. Just 1° north is the remarkable rich open cluster NGC 7789.

Σ3050 Andromedae 23h 56.9m, +33° 27′ (mags 6.5, 6.5; sep. 1.5″; p.a. 309°, 1980). An ideal test pair for 3-inch scopes, this binary pair is in the process of closing.

Kappa^1 ($\varkappa^1$) Sculptoris 0h 06.8m, -28° 16′ (mags 6.2, 6.3; sep. 1.4″; p.a. 265°, 1954). This is another 3-inch test, although its far-south location may make $\varkappa^1$ Scl all but impossible for observers from the northern U.S. and Canada.

55 Piscium 0h 37.3m, +21° 10′ (mags 5.6, 8.2; sep. 6.5″; p.a. 194°, 1939). I'll never forget that crisp autumn evening when I first saw this beautiful pair. Like ξ Cep, this is one of those remarkably close, unequal doubles that captivates its viewers. Look for the strong yellow and blue colors and for 54 Piscium, which lies in the same field.

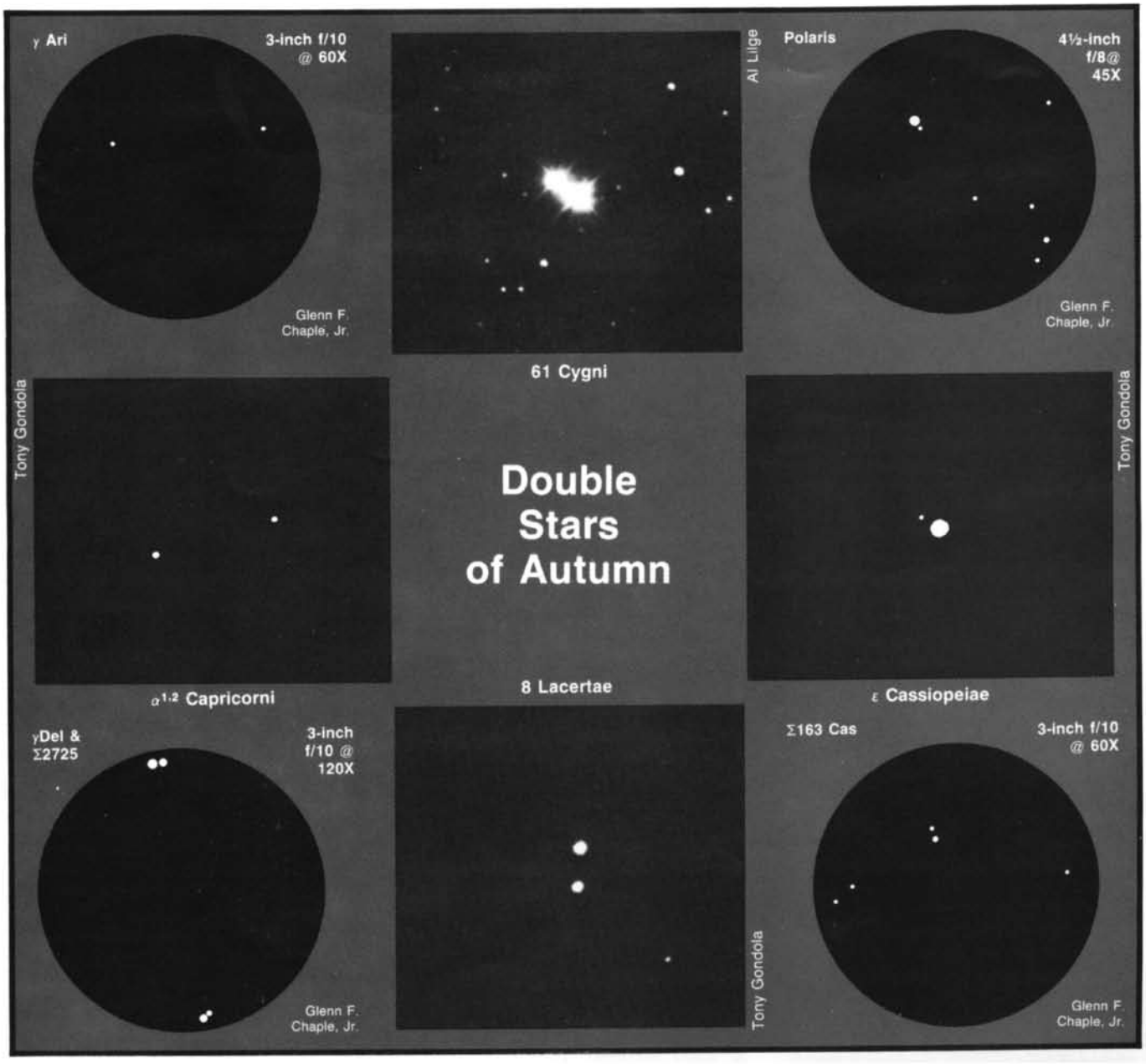
Alpha (α) Cassiopeiae 0h 37.6m, +56° 16′ (mags 2.5, 9.0; sep. 64.4″; p.a. 280°, 1913). The golden yellow primary and its bluish companion show a nice contrast. This is an optical pair that is slowly widening. Try the "pendulum effect" (see ε Peg above) on this wide, unequal twosome and let me know your results.

Eta (η) Cassiopeiae 0h 46.1m, +57° 33′ (mags 3.6, 7.5; sep. 12.0″; p.a. 307, 1980). Eta Cas is a slow-moving binary with a period of about 500 years. What makes this double so special is its remarkable color scheme — yellow for the brighter star and red for the lesser. The colors are obvious when this system is viewed with a 6-inch scope.

65 Piscium 0h 47.2m, +27° 26′ (mags. 6.3, 6.3; sep. 4.4″; p.a. 297°, 1959). 65 Piscium is a beautiful twin system whose separation provides an ideal resolution test for a 1-inch scope.

Zeta (ζ) Piscium 1h 11.1m, +7° 19′ (mags 5.6, 6.5; sep. 23.6″; p.a. 63°, 1959). Pisces may be an inconspicuous star group, but it contains some spectacular double stars. Zeta Piscium is no exception — observers tend to disagree on its colors. What's your opinion?

1 Arietis 1h 47.4m, +22° 02′ (mags 6.2, 7.4; sep. 2.7″; p.a. 166°, 1962). Here's a pair to challenge owners of 2.4-inch (60mm) refractors. Larger scopes pick up the gold and blue colors.



To find 1 Ari, look 2° northwest of β Ari.

Σ163 Cassiopeiae 1h 47.6m, +64° 36′ (mags. 6.2, 8.2; sep. 34.8″; p.a. 35°, 1936). Look about 1½° north of ε Cas to find this splendid orange and blue duo.

Alpha (α) Ursae Minoris 1h 48.8m, +89° 02″ (mags 2.0, 8.8; sep. 18.4″; p.a. 218°, 1955). Polaris, the North Star, is the classic light test for 2- or 3- inch scopes. The faint star, masked by the glare of its luminous partner, can usually be glimpsed with averted vision. In a 6-incher, Polaris is easily resolved and shows yellow and blue colors. (By the way, Polaris is also a 3.97-day Cepheid, with a 0.1 magnitude range.)

Gamma (γ) Arietis 1h 50.8m, +19° 03′ (mags 4.8, 4.8; sep. 7.8″; p.a. 360°, 1959). One of the finest double stars in the heavens — especially for small scopes. The sight of these gleaming white twins suggests cat's eyes or the headlights of a distant automobile.

Alpha (α) Piscium 1h 59.4m, +2° 31′ (mags 4.3, 5.2; sep. 1.7″; p.a. 281°, 1980). This binary system will become increasingly difficult as it closes to 1.5″ by the end of this century and continues to a minimum separation of 1.0″ around the year 2074. Right now, it's a good test for a 3-inch scope.

Double Takes If you have the previous three issues of DEEP SKY, you can now lay claim to a complete list of 100 of the finest double and multiple stars in the heavens — 25 for each season. Naturally amateur astronomers from below the equator may have a few things to say about these selections, since our southerly limit of −40° declination reflects a mid-northern latitude bias. Two notable "far-south" pairs — α Cru and α Cen — would easily make the "Best Ten" list of any U.S. or Canadian observer, were they positioned further north in the sky.

Gus Johnson, of Swanton, Maryland, knows how to get mileage out of a small scope. Using a 2.4-inch f/15 Unitron refractor, he was just able to see as elongated the closest two members of the triple star ζ Cnc. These are currently separated by 0.8″, and require an 8-inch for a clean split.

Hope, Indiana, observer F.D. Bruner sent in a fine set of notes he made on some of the showpiece summer double stars featured in the last DSM. Of particular interest were his comments on Antares, which he split with a 6-inch f/15 refractor at 250x. "Although I used no filter last night, I have found in the past that a green Wratten 56 or a blue Wratten 38A filter does wonders with this star." Do any other DSM readers use filters to observe double stars? If so, I'd like to hear from you.

82 South Harbor Road
Townsend, MA 01469

On Beyond Predictability

by David H. Levy

I *hate* right-angle finders. Here I am at the start of a crystal clear October night, and I can't find anything through this new right-angle finder of mine. All the charts are reversed right to left, and finding a variable star is next to impossible. I know that entropy is increasing, but why help it along?

So a precious half-hour goes by as I replace the finder and start an observing session — showing a group of bright fourth graders the sky — that begins with a very predictable variable star and gradually moves on to those whose behavior is wilder and more deviant. At the outset, I rather flippantly suggested that **Delta (δ) Cephei**, whose period is known to several decimals of a day, was a star that would capture the mind and heart of an accountant. The children had brought their parents and one piqued father demanded to know why accountants like himself could not also be productive variable star observers.

"You can," I replied lamely, "with stars such as Delta Cephei." I tried to explain how the Cepheids have long been famous as milestones in our corner of the universe. That didn't help. I tried to emphasize the historical importance of Henrietta Leavitt's work — she who discovered that the periods of these stars are proportional to their mean absolute magnitudes. That got his interest, but he was still upset.

There was nothing else to do but to persuade him to observe the actual changes that occur in this star himself.

"But we can't afford a telescope," he said.

"You don't need one," I said firmly. "Binoculars will do fine. Begin by looking at this chart of Delta and Mu (μ) Cephei." So far, so good — he likes charts. "Delta Cep has two neighbors, Zeta (ζ) and Epsilon (ε). To measure Delta's brightness, let's assign an arbitrary value of 1 to Zeta and 5 to Epsilon. If Delta is as bright as Zeta, we'll call it 1; if it's slightly fainter than Zeta, we'll label it 2; if it lies midway between Zeta and Epsilon, we'll call it 3; if it's slightly brighter than Epsilon, it's 4; and if it's as faint, we'll assign 5."

My accountant friend found Delta Cep in the sky with his binoculars, tried the system, and recorded Delta as "2." It worked! He was now a confirmed variable star watcher, and was soon estimating actual magnitudes, comparing Delta directly with 3.6 magnitude Zeta and 4.2 magnitude Epsilon.

A Mira Star

Our next star: **R Andromedae**, the first known variable in the constellation of the chained princess. Using the AAVSO's "a" chart, you can hop to the star's vicinity from the Andromeda Galaxy (M31). You then switch to a "b" chart, which has south at top to match the view in a telescope and has a larger scale. This puts M31 off the map, so you'll have to match up the plotted star patterns with the view in your scope to locate the variable.

But if your telescope has a star diagonal or zenith prism (like the right-angle finder), you'll find the chart almost impossible to use, since the image in your eyepiece is reversed left-for-right. Some observers get around this by turning the chart around and shining a light through it. This works pretty well, but of course the labels are all backward. (I think the standard Newtonian reflector is the best instrument for variable hunting!)

R Andromedae shows a regular pattern of variation, but not nearly so much as Delta Cep. R's period is known to an accuracy of a few days, as are those of most of the long-period variables (LPV's) of which it is representative.

By the way, did you know that R Cygni is also a long-period variable? And R Leonis? The reason for this is that R is the designation given to the first variable discovered in any constellation and since long-period variables were found easily, it's hardly surprising that the "R" variable star in many constellations is also an LPV. Such stars have very large ranges: R Andromedae fluctuates nearly 10 magnitudes — from 5.3 to 15.1.

As the Night Goes On

The night grows older. New and different stars rise in the east. There will surely be enough to keep us going the entire night if we wish to stay up that long. As Cetus rises, it brings perhaps the most wonderful variable star of all, and the first long period variable to be discovered. And then, later on, we can look toward Perseus to see a slowly fluctuating "semiregular" star. My accountant friend and his son have long since gone home, and these new stars will have to do without them. But the new stars are less and less predictable — and later on toward dawn, we'll meet stars that follow no reason at all.

In 1596, David Fabricius noticed a fairly bright star in Cetus. Over the following weeks he watched it gradually fade until it disappeared. He saw it again in 1609, the year Galileo turned his new *perspicillum* skyward. By 1639 a number of sightings had confirmed that this star was a variable.

Named **Mira** ("the wonderful") and catalogued as Omicron (ο) Ceti, this star ranges between magnitude 3 and 9 over a period of 331 days, but the figures are deceiving — Mira does not always behave on cue. In 1799 William Herschel remarked that it rivaled 1st magnitude Aldebaran in brightness, although at other maxima it may barely reach fourth magnitude.

The task of "discovering" Mira today, almost 400 years later, is much easier but no less exciting. The AAVSO charts show the variable in two ways: the "a" chart should be used with unaided eye or binoculars and is useful both for finding Mira and for estimating its brightness. The "b" chart, with south up, is for use with a telescope. When Mira falls below 5th magnitude, you should haul out your scope and use the comparison stars on the "b" chart.

Because of their similar behavior, thousands of stars are now known to be Mira-type (LPV) variables — in fact, it's the most numerous class of variable. They change brightness over a period of several months, but their amplitudes and periods aren't completely predictable. Mira still pulls enough tricks and surprises to be well worth watching.

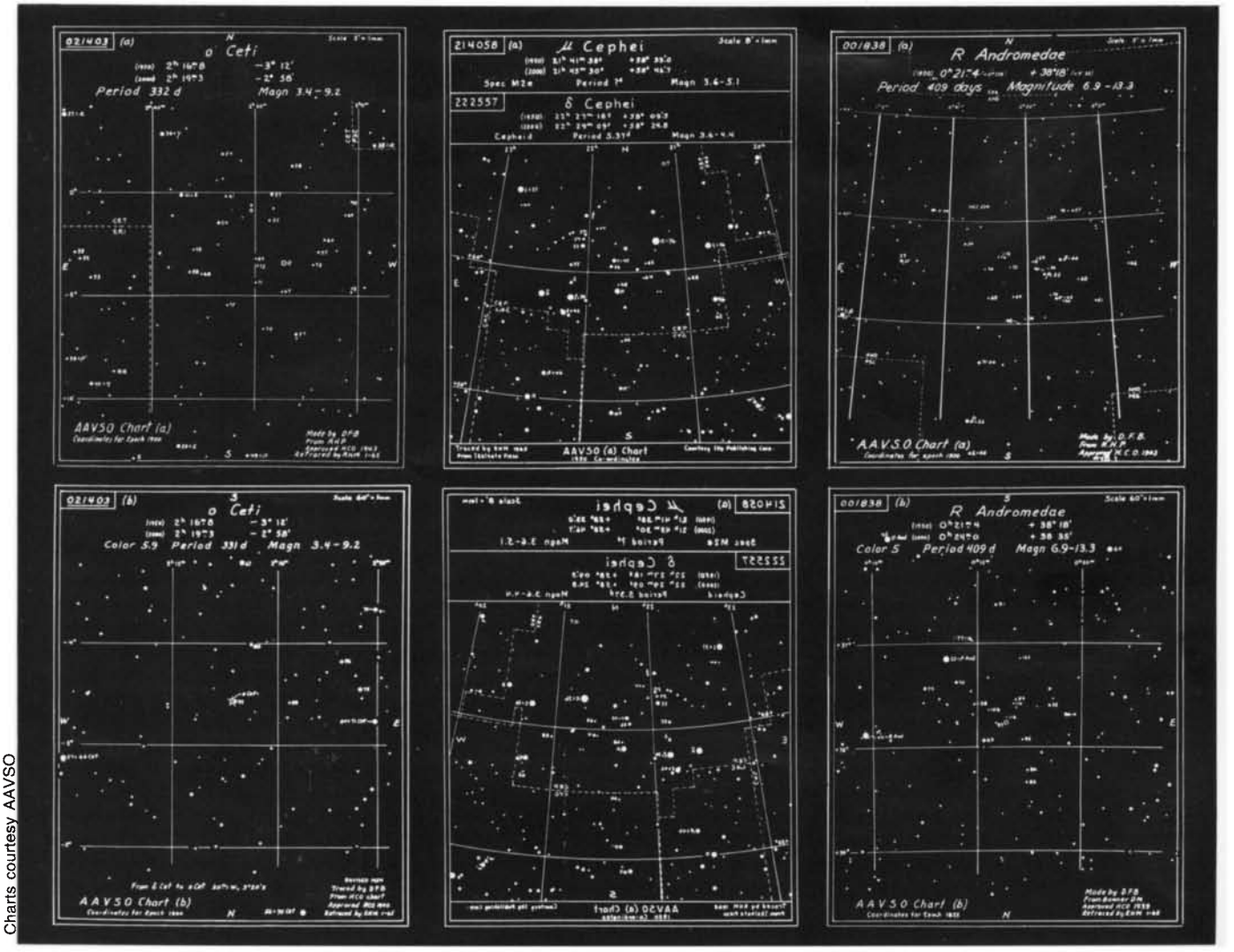
Another interesting class of star is the semiregular variables, red giants whose periods and ranges are far less certain than the LPVs. Tonight's semiregular star, **S Persei**, does not need watching every night. Compared to other variables we've looked at, its changes are glacially slow. While S Per does have a rough range and period (magnitude 7.3 to 11 over about 800 days), they are loose averages — based on many years of observations — and don't necessarily reflect the star's current behavior.

It is best to check stars like S Per once a month. (And in this case your observations yield a bonus — a simultaneous look at one of nature's finest sights, the Double Cluster in Perseus, which it lies in.) After you estimate S Persei's magnitude, remember to record the date and time as well as brightness (to tenths of a magnitude) as soon as possible. If you have a Julian Day calendar, record Julian Day (to tenths of a day) and magnitude.

As Dawn Approaches: the Star Factory

Buried deep in the richest part of the predawn autumn sky is the constellation of Orion the Hunter, a group of stars all related in a special way: Betelgeuse excluded, all the bright stars in Orion lie at about the same distance from us. Orion is more than a place in the sky, and far more than a figure from mythology; it is a cosmic star-production plant, one whose different divisions show us how stars are made.

The process of star formation is very



Charts courtesy AAVSO

complicated but at least we have found a way to see how it takes place. Young stars in the belt of Orion represent a group of stellar children whose formation is essentially complete. M42 itself may be only a few tens of thousands of years old, and the stars within it are probably no older than a million years. Astronomers believe that two regions to the north of the "Trapezium" have formed stars even more recently. Throughout the constellation are huge clouds of hydrogen which, given another several million years, may coalesce into stars. So Orion's star factory seems to consist of at least three regions with the earliest stages at the southernmost end of the constellation and the later stages around the belt.

Let's focus a little more carefully in the middle area where stars are in the process of birth — M42, the Orion Nebula. As any observer can say, its appearance is stunning, and if your skies are dark its detail is exquisite. With a 4-inch telescope, you can make out the beginnings of the complex dark and light gases that shape the nebula. With an 8-inch and a dark sky, the region explodes into a labyrinth of convoluted nebulosity that surrounds dozens of suns. Toward the south, you begin to perceive a large loop of faintly glowing hydrogen. And if you get a peep through a 16-inch instrument, the delicacy and complexity of the strands of nebulosity are overwhelming. Delicate color is sometimes visible in such large scopes, especially a subtle fuchsia. It is surely an awesome sight: 35 light-years of gas from end to end, shining from a celestial stage 1600 light-years away.

The most common type of variable star behavior in Orion manifests itself as a rapid and highly irregular flicker. The stars vary by as much as a fifth of magnitude in 20 minutes. For this reason, it is necessary to watch these stars very closely; in fact probably once every 10 or 15 minutes. You should also choose comparison stars with great care, since some candidates may themselves be variable. **NV Orionis** is an example of this type of variable; one night I witnessed it drop half a magnitude in just one hour!

The second pattern of variation is something like that of R Coronae Borealis, in which unpredictable drops in brightness interrupt long periods of steady light. **T Orionis** behaves this way quite frequently and at one time was even classified as an R CrB star. But just as two people whose different diseases occasionally show similar symptoms, R CrB's variations and T Orionis' are apparently unrelated. R CrB is an older star that may emit some form of dust into its atmosphere, while T Ori's changes are due to, possibly, thicker amounts of nebulosity passing in front of the star.

Other Orion stars have much flatter light curves. During the five years I've observed it, **MX Orionis** hasn't varied by more than one fifth of a magnitude. And there is the **V361 Orionis** type, which consists of stars so close to the center of nebulosity that it really is impossible to estimate their brightnesses visually. The nebulosity just keeps getting in the way, confusing you.

Estimating these stars' brightnesses is a very difficult process, so exacting, in fact, that the AAVSO no longer encourages visual observations of them. So why bother at all? Because the Orion variables represent an important phase in the early evolution of stars, and by viewing these stars you can attempt to understand how young stars work.

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A Night on Kitt Peak

"But what do you want?" the young Indian demanded of the slender streak that had just lit up the darkening sky. Exhausted by the climb to his warm weather home half a mile above the valley floor, he took a long look at the growing numbers of twinkling lights in the sky above him. Whatever they might want from him, they must want it more from here — for somehow the lights seemed brighter than they were from the valley. Each year he and his people moved to the top of this mountain. Each year they asked the same question. Each year they wondered.

A hundred centuries later — from the very same spot — different people, peering now through eyes of glass and steel, also wonder. Slowly the shutter slides open, allowing at first only a narrow slit of sky to appear. But as the two giant pieces of curved metal continue to move apart, the glow from a mountaintop sky spills in to fill the room with the eerie dim light of approaching night.

The day had been spotlessly clear: not even cirrus threatened. On top of this 6800-foot mountain in southern Arizona, more than a dozen telescopes are now awakening for a night of observing. I can barely see the silhouette of our telescope, the #2 36-inch Classical Cassegrain, with its photometer for measuring the thin trickle of light from tiny asteroids. I felt a cold shudder just from looking at the box of dry-ice which surrounds the photometer and chills it to its frigid working temperature.

Still the slit widened. I wondered if the awe I felt as night came on was the same as that experienced by the young Indian centuries ago. Both he and I share memories of the beauty of thousands of evenings. But why is this one different? Perhaps the opening slit far above me offers a fresh perspective to an old event. Is not the narrow slit symbolic of the way of science, the logical process of understanding the universe — one night at a time? Tonight we won't look at the whole sky. Tonight we'll study only a handful of selected objects. Tomorrow we'll examine a few more, and hour by hour, night by night, we'll increase our understanding.

Now the slit is fully opened, culminating the hours of preparation for tonight, and it is time to get to work. I'm assisting a group called the Planetary Science Institute, four of whose scientists — Clark Chapman, Donald Davis, Richard Greenberg, and Stuart Weidenschilling — are investigators on a geodetic survey of certain asteroids. This long-term research brings us to the mountaintop and the #2 36-inch telescope ten times a year as we try to obtain precise light curves for our chosen asteroids. The data we get are especially valuable if we can obtain full curves, and for each curve we need four to six hours of "photometric sky" — skies uninterrupted by even light cirrus. By obtaining these full curves at varying aspects of the orbit of an asteroid, we can derive its physical shape and perhaps learn something of its history.

I had stored positional information into the telescope's computer earlier in the day which now gets called up as the telescope slews toward the first asteroid's position. Electronically, I order the photometer to begin its five second integrations of photons from the asteroid. After three or four such measurements, the telescope automatically offsets a minute of arc to the north so it can measure the sky background, which is then subtracted. I then call up the position of a chosen nearby comparison star, and since this is usually within a degree of the asteroid, the telescope finds the star by itself — unless I choose to speed the process along by helping the scope. The comparison star is measured the same way. We repeat this for up to three asteroids at a time — as some sink too low to the horizon, others higher up take their place.

We also have a list of six "standard" stars that we observe both in visual and blue light. Three times during the night we check the standards, observing them at different elevations. For twelve hours the work continues, integration by careful integration.

Twenty-five years ago, the National Observatory began on Kitt Peak, a site chosen partly for its relative lack of cloudy nights. While Kitt Peak is not a perfect site, it offers significant advantages over others. One of the lesser-known ones is that its position near the Mexican border is south of most of the routes of the airlines, whose cirriform-producing planes decorate the clear sky to the north toward Phoenix. As at most mountaintop sites, a disadvantage is the wind. We've lost hours of work during which we would stand outside looking forlornly up at a diamond-clear sky while 45-mph winds kept every dome on the mountain shut tight. On other nights, the enemy was dust or pollen. But tonight, our work is delayed for a technical reason. It seems that the two filters in our photometer are not changing properly, and this apparently minor difficulty is robbing us of a major part of our early observing hours.

While the technicians struggle over our photometer, I decide to walk outside for a while. The Moon has set, and the mountain domes are illuminated by the faint airglow that is easily visible on dark nights, as well as by the soft light of a billion suns. Quiet sounds carry over the dark mountaintop — domes are turning and observing platforms are rising and falling. Each building has its peculiar tone; the larger ones produce basso profundo hums in harmony with the higher whines of the smaller domes, while the venerable dome of the 50-inch chimes in from time to time with a solid percussive bump. Apart from these noises, the mountaintop is bathed in

Kitt Peak from the Air KPNO

profound silence. It is a silence surrounded by miles of apparent nothingness. I look toward the south, across the ridge of the Quinlan Mountains toward Baboquivari Peak, and can see no sign of civilization whatsoever. This is a land of peace and quiet, of flora and fauna, and of dark nights.

Kitt Peak is a telescope cornucopia that is unmatched, at present, anywhere else on this planet. Our #2 36-inch is flanked on its west by a 16-inch and another 36-inch telescope, as well as by an unused Polaris-seeing dome. On the other side, far to the southeast, stands the solar complex of McMath and Vacuum Telescopes. The McMath actually consists of three telescopes in one: three independent light-gathering systems sharing one very long tube. Between the solar complex and our 36-inch stands the 84-inch which I remember visiting back in 1963 as a child. "It is available to qualified personnel," the guide had explained, with a sneering emphasis on the "qualified." I wondered at the time where I would be two decades later.

Off to the north, dwarfing all else by comparison, looms the dome of the mighty 4-meter Mayall telescope. During a storm last month, I discovered that underneath the observing floor of the 4-meter was a wonderful series of rooms that includes a piano. A new activity for cloudy nights!

Dwarfed by the nearby 4-meter is another famous telescope, Bart Bok's 90-inch, which belongs to Steward Observatory. This fine instrument is housed in a strange, hemispherical shell rather than a traditional dome: a reflection, perhaps, of the unique vision of its builder. Bart Bok knows how to build and run observatories, said the National Science Foundation. He wants a 60-inch. We'll turn the 6 upside down and fund a 90-inch telescope!

Nearby is Steward's 36-inch telescope, the only major instrument on the hill with a Newtonian focus. This is the telescope through which — while it was in Tucson — the Papago Tribal Council looked. The Papago representatives gained respect that night for "the men with the long eyes" and, not long after, they leased the mountaintop for the National Observatory. And from its new home at that observatory, the 36-inch became the first telescope to see an optical pulsar — the one in the Crab Nebula.

Looking over the mountaintop, I can see its quarter-century of history. But what of its future? Will another instrument one day join the "Telescope National Forest"? Can the observatory afford the upkeep of what it has already? I'm now standing a few feet from the #4 16-inch, which was closed through most of 1982. And our own 36-inch stayed open only during "dark times" for some months during the budget crunch of that year. And what of room on the mountain? Kitt Peak is becoming crowded....

Ah, the filters are fixed! The 36-inch is on-line once more, and we continue our asteroid work. The observer with whom I am working tonight is Clark Chapman, a planetary astronomer of international reputation. While we observe, he describes his early

David H. Levy

The #2 36-inch

beginnings with the stars, with a small telescope and the Association of Lunar and Planetary Observers. No wonder he can move this leviathan around with the ease of a small reflector. Using two control panels — one fixed on the floor and another in his hand — he moves the telescope in two axes, swings the dome 100° to the east, and drops the observing platform. All three stop almost at the same instant and the long telescope points to within a degree of the asteroid's position. While this happens, I type in a series of commands to prepare the photometer to integrate. Then we move to background, then to comparison star and its background, and then we are ready for the next object on the program. Total elapsed time: 210 seconds. I have a great deal of respect for Dr. Chapman and the three other observers with whom I work. Each performs nimbly with telescope and observatory to produce beautiful music. My task is to check the score.

The night is long. I began work at 4 p.m. with an introductory conversation via a computer terminal. Aside from an intermission for supper and the technical delay, we have had no breaks. What is the worst threat to our observing? It's not the high winds nor the dust that keeps the dome closed while the stars shine brightly. Nor is it the storms that pass through here with such frequency in winter. The real worry is cirrus clouds. The thinner they are, the more devastating their effect. With the other problems, we know when to shut down. But sometimes we do not even notice the cirrus and work through a whole night gathering data that are essentially useless. We must always be vigilant for this sneaky "data killer."

Cirrus does not seem to be with us tonight. As the data continue to come in, I check it in two ways — first, the three integrations should be within one percent of each other, and second, the comparison stars should remain constant from earlier readings. On both counts, the data look good. The comp star has apparently brightened a bit, but it is also still rising higher in the sky. We're in business!

It's 11:30: we're getting hungry. Fortunately our time-line — the paper commandant that dictates what we observe when — has only one object on it for the next few minutes. We use the break to check the standard stars once more, and then I go to the dining hall to fetch night lunch. The rarefied atmosphere, the hard work, and the excellent food make night lunch an event not to be missed.

Again I hear and see the symphony of domes. They all seem to be moving tonight, a good sign that technical glitches are probably not interfering with anyone's research. The technical assistants, possibly described more appropriately as very capable telescope doctors, tell me that the clear, calm nights usually have the least technical problems. It's the nights when clouds come and go that problems seem to appear mysteriously out of nowhere.

Night lunch could not have come at a better time. We were getting a bit tired, and the sandwiches and coffee, taken at intervals throughout the rest of the night, will keep us going until dawn. On returning I learn that our cold box is hungry too, so I refill it with enough dry ice to keep the photometer happily cold the rest of the night.

And as the night rolls on both observer and assistant continue to gather data: object to background to comp star to background to new object, trying to keep our observations separated by no more than 10 or 11 minutes, and keeping watch on the sky at the same time for possible cirrus. Because there is no easy access to the outside from this dome, the sky watch is a bit cumbersome. Occasionally I go downstairs and out the door to look at the sky, while the observer continues to run the telescope. In the larger domes where data are monitored from a comfortable heated observing room, observers occasionally forget about the state of the sky. On one night, a fog forced all domes to close except the largest, whose base actually was above the cloud top. Unaware of the cloud and its accompanying high humidity, the 4-meter man kept right on working, until his assistant happened to leave for night lunch and couldn't find his way through the fog!

All observatory domes should be designed for easy outside access for quick weather checks. When Bart Bok designed the 90-inch, he ordered that a special walkway be constructed at dome level. The obliging contractor built the porch, including a special sign that reads "The Bok Walk." That's one reason why that astronomer's data are never clouded out.

Only two hours are now left until dawn, and with the pace of our work, I wonder how we shall ever make it. Sitting next to me is a tiny refractor I carry, and with it I take occasional glances at the mountaintop sky. But even with this diversion I am beginning to tire. After all, we have been working for five straight nights. Tomorrow will be the last of this run. I think of the long nights that observers earlier this century have spent in their domes. I think of Milton Humason at the focus of the 100-inch Hooker reflector on Mt. Wilson. I recall Clyde Tombaugh telling me of the nights at Lowell, patiently preparing his plates for the long dark spell of each lunation as he searched for the elusive "Planet X." And I look at the observer beside me as he checks the position of our next asteroid with care. I am awake now. In company such as this, second wind comes easily.

Toward dawn we have to be especially careful, because that is when the sky condition may change. On cue, the wind picks up. Our dome slides toward the south so that we can watch asteroid 201 Penelope as she whirls rapidly on her axis. And finally, another check on 1620 Geographos, an Icarus-type asteroid that is not too far from Earth. Earlier we saw it moving through the aperture of the photometer as it dashed across the sky.

Thanks to a special reduction program, our observing continues well into the brightening sky. But soon, even the asteroids become too faint to see. We take the last of our readings and close down. In opposite order from the set-up procedure that seemed to have taken place so long ago, the equipment is brought to a state of rest. The shutter closes — it seems so long since it opened half a day ago.

Over the Rincon Mountains far to the east, the sky is now brightening rapidly, but because of the altitude, it is not very red. The brightening localizes, and then suddenly, a green spark marks the end of the Sun's eclipse by the bulk of the Earth. And as the green quickly turns to yellowish red, we know that the long night's journey into day is finally over.

During the time it takes the Sun to climb above those distant peaks, I am reminded of a poster hanging inside the Planetary Science Institute down in Tucson. "Good planets are hard to find," it advises. Especially a planet where we can watch a young child look at a blossoming flower. Or where we can watch a mountain squirrel gather nuts for his winter. Or where we can look up at night and marvel at the stars.

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A Starhopper's Guide to Messier Objects
by Lenore Freeman
Everything in the Universe
Oakland, 1983
28 pages, 8½"x11"
paper, $6.95

Deep Sky Detail Charts
by Thomas A. Sarna
Sarna and Associates
Downers Grove, IL, 1983
102 8½"x11" charts + finder map
paper, $30

The Visibility of Deep-Sky Objects
by Fred Klein
Klein Publications
Los Altos, CA, 1983
283 pages, 6"x8½"
paper, $28.95

During the last few months, three important deep-sky related publications emerged, signaling an ever increasing interest in amateur deep-sky observing. This is encouraging to those of us who are interested in looking at and photographing clusters, nebulae, and galaxies, but it is not surprising. During the last few years, we've seen a dramatic increase in interest toward deep-sky objects primarily because of the Dobsonian revolution and commercial manufacturers' quick response in offering similar short focus, large aperture instruments. Most of this started taking place in 1978: now, five years later, we're seeing a rush of publications perhaps inspired by, or just timed for, the new generation of deep-sky observers.

Whatever the authors' intentions, these three publications — all of which were "privately" published — are extremely useful. Rather than doing a general book on observing, a very costly time-consuming venture, these authors all discovered an unfulfilled specialized niche and filled it, inexpensively and efficiently. They accomplished something that multitudes of observers *thought* about doing, but haven't.

Probably the most appealing to relatively new observers is Lenore Freeman's *A Starhopper's Guide to Messier Objects*, published by Everything in the Universe. This book is the perfect little "star atlas" for beginners interested in deep-sky objects: it is uncomplicated, free of clutter and Greek notation, and consists of 18 constellation charts showing bright stars only and progressively fainter ones nearing the Messier objects. Slickly calculated for star-hoppers — which most observers are, I suspect — the book is all you need to track down the entire list with a small telescope, providing you have a sufficiently adequate finderscope. It also contains a list of the Messier catalogue and three large-scale sky maps, showing the constellations' positions in relation to each other. *A Starhopper's Guide* is only 28 pages long, but that's all it need be to serve its purpose. One drawback: the paper is very thin and flimsy. The book is still a good buy at $7: remember that you're paying for information, not production quality.

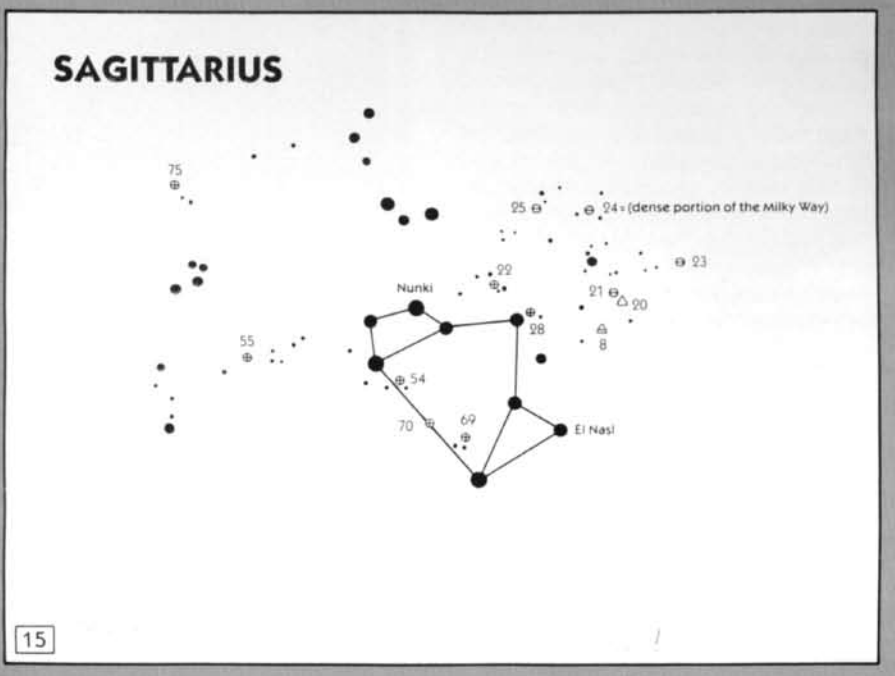
If you've seen the Messier objects and want something new to look at, or if you have a large (10-inch to 20-inch) telescope, consider Tom Sarna's *Deep Sky Detail Charts*. This atlas is essentially the *Starhopper's Guide* taken a step further: it consists of 102 positional charts which accurately locate 115 galaxies, 56 open clusters, 41 globular clusters, 25 planetary nebulae, and 17 bright and dark nebulae (all of the Messier objects and an additional 147 NGC objects). The set also comes with a poster-size fold-out sky map showing the brightest and best objects and constellations.

Why should you want to get this atlas? Probably all of the objects on it appear on the *Sky Atlas 2000.0*, which you might well already own. But any observer who has spent a night with a large telescope knows exactly why you will want Sarna's work if you use a large scope. The *Sky Atlas 2000.0*, although a fine general all-sky reference, has a relatively small plate scale of 8.4′ per millimeter. Go out with a 12-inch scope at medium power and a 3-inch finder, and the real sky looks completely different than what shows on your atlas! Sarna's *Deep Sky Detail Charts* each have a plate scale of about 1′ per millimeter, making their scales eight times larger than the popular star atlases. They also, of course, show much fainter stars — although the charts should not be used for magnitude comparison.

To use one of the charts, all you have to do is center the telescope, using a low power eyepiece, on a bright guidestar. (The Andromeda Galaxy chart, for example, suggests β Andromedae as a starting point.) Then follow the coordinate directions on the chart: the M31 chart instructs to move 27.0m west in R.A. and 5°39′ north in Dec. from the star. The Great Galaxy should be centered in the field. To find additional objects on the charts — most show more than a single target — you simply star-hop using the field stars. If you don't have setting circles on your scope, you can use a general star atlas to move into the right area, then switch to Sarna's chart to specifically narrow in on the correct starfield.

The price of $30 is quite fair, considering the enormous expense of making these charts and the small press run — again, you're paying for the expertise and information. The printing quality is pretty good: the charts measure 8½"x11" and are printed in blue ink, which contrasts well with red flashlights. They are on heavy card stock, but are still susceptible to moisture — be careful with them when you take them outside (you almost want to Xerox them, take the copy and use it, and keep the original inside). If you have a large telescope and observe

Chart 15 from *A Starhopper's Guide*: *The perfect little star atlas for beginners.*



28 OBJECTS BY RIGHT ASCENSION 29

NAME	RFT	TYPE	VIS	CONST	RA-(1950)-DEC	MAG	SIZE/SEP	ATLAS	RA-(2000)-DEC	DESCRIPTION	Q	REFS
ALPHA HERCULIS, RASALGETI		COLOR DBL	5	HERCULES	17 12.4 14 27	3-4,5.4	4.7"	15,X	17 14.7 14 23	RED-YEL,1968	A	HMG
DELTA HERCULIS, SARIN		DBL. STAR	6	HERCULES	17 13.0 24 54	3.1,8.7	8.8"	8,IV	17 15.0 24 50	1961	C	HMG
BARNARD 64, M9		DARK NEB.	X	OPHIUCHUS	17 14.4 -18 29	-	5'	15,X	17 17.3 -18 32	-	C	
OMICRON (39) OPHIUCHI		COLOR DBL	3	OPHIUCHUS	17 15.0 -24 14	5.4,6.9	10.8"	22,XIV	17 18.0 -24 17	YEL-BLU,1951	B	
M92 (NGC 6341), BARNARD 64		GLOB.CLUS	3	HERCULES	17 15.6 43 12	6.5	8'	8,IV	17 17.1 43 8	MAG 12 STARS	B	HM W
M9 (=NGC 6333)		GLOB.CLUS	4	OPHIUCHUS	17 16.2 -18 28	7.9	2.4'	15,X	17 19.1 -18 31	MAG 14 STARS	C	H W
NGC 6337		PLANETARY	4	SCORPIUS	17 18.9 -38 25	10S	38"X28"	22,XIV	17 22.3 -38 27	RING	C	
BARNARD 72, THE SNAKE	R	DARK NEB.	X	OPHIUCHUS	17 21.0 -23 35	-	4'	22,XIV	17 24.0 -23 37	SINUOUS	B	
RHO HERCULIS		EQUAL DBL	4	HERCULES	17 22.0 37 11	4.6,5.5	4.0"	8,IV	17 23.7 37 8	1964	A	HMG
NGC 6369		PLANETARY	5	OPHIUCHUS	17 26.3 -23 44	11	28"	22,XIV	17 29.3 -23 46	RING	B	
NGC 6362		GLOB.CLUS	4	ARA	17 26.6 -67 1	8	9'	26,XVI	17 31.7 -67 3	MAG 14 STARS		
NU DRACONIS, KUMA		EQUAL DBL	O	DRACO	17 31.2 55 13	5.0,5.0	62"	3,IV	17 32.2 55 10	1955	A	HM
53 OPHIUCHI		MULT.STAR	2	OPHIUCHUS	17 32.2 9 37	5,71111	41"94"91"	15,X	17 34.6 9 34	1949		
NGC 6388		GLOB.CLUS	4	SCORPIUS	17 32.6 -44 43	6.8	3.4'	22,XIV	17 36.2 -44 44	MAG 17 STARS	C	
M14 (=NGC 6402)		GLOB.CLUS	4	OPHIUCHUS	17 35.0 - 3 13	7.6	3'	15,X	17 37.6 - 3 14	MAG 15 STARS	C	H W
NGC 6397		GLOB.CLUS	2	ARA	17 36.8 -53 39	5.7	19'	26,XIV	17 40.8 -53 40	MAG 10 STARS	A	
M6, BUTTERFLY CLUSTER	R	OPEN CLUS	4	SCORPIUS	17 36.8 -32 11	6	25'	22,XIV	17 40.0 -32 12	50 STARS	A	HM W
IC 4665	R	OPEN CLUS	3	OPHIUCHUS	17 43.8 5 44	5.9	60'	15,X	17 46.2 5 42	13 STARS	C	
NGC 6440, NGC 6445 (PL)		GLOB.CLUS	6	SAGITTAR.	17 45.9 -20 21	9.7	0.7'	22,X	17 48.9 -20 22	V.FAINT STRS	A	
NGC 6441		GLOB.CLUS	4	SCORPIUS	17 46.8 -37 2	7.4	3.3'	22,XIV	17 50.2 -37 2	MAG 17 STARS	C	

deep-sky objects, this is a valuable item for you and certainly a worthwhile investment. Even if you have a small telescope but want a record of the area surrounding deep-sky objects to help guide you in observing, consider this work.

The Visibility of Deep-Sky Objects, unlike the previous two publications, is a tabular listing of data about the finest stars, clusters, nebulae, and galaxies. Compiled and published by Fred Klein, this 5-book set is a computer-printout compendium of statistics on over 2400 objects: it is an extended outgrowth of Klein's 1981 booklet *A New List of 450 Deep-Sky Objects for Amateur Telescopes*. The series now provides type, 1950 and 2000 epoch coordinates, magnitude, size, separation, a short cryptic description, atlas chart references, and a "visibility class" number for each object listed. The book is a very handy summation of data — a shortcut to chasing through books to discover what, for example, the diameter in arcseconds is of planetary nebula IC 4406 in Lupus. Or a thousand other such questions.

But the innovative aspect of the book comes from the visibility class: Klein hit the nail on the head, realizing that surface brightness is the critical factor in deep-sky observing, not integrated magnitude. Capitalizing on this, he squared the diameters of objects and plotted them against magnitudes, drawing curves to separate classes. This system provides an interpretation of how easy or difficult it is to observe these objects. Bright galaxy NGC 253, for example, rates a "1" — easy to see — while fainter and face-on M74 rates a "6." The system occasionally breaks down in practical terms, such as listing clusters M44, M7, and the Double Cluster in class "3." Certainly they should rate higher since they are obvious, bright naked eye patches. The elusive Rosette Nebula falls into the same class as high surface brightness M17 in Sagittarius. But used generally, the guide is a valuable indicator of the visibility of deep-sky objects.

The set's first volume ($7.95) lists 500 of the brightest objects by right ascension, visibility, and object type. Volumes 2 and 3 together ($12.95) list data for over 2,400 objects: the third volume lists galaxies and the second everything else. Volumes 4 and 5 ($12.95) contain the same information as the previous two, but organize it by *Sky Atlas 2000.0* charts. Anyone who is interested in a handy, organized, up-to-date reference for basic data on the bright deep-sky objects should jump at Klein's books. It is much more useful than most such lists, and contains a special, highly functional advantage — the insight of understanding just exactly what does make a nebula or galaxy easy or tough to find. — *Dave Eicher.*

Above: A section of text from *Visibility*. Below: Chart 81 from Sarna's Atlas: *A valuable item for large scope owners.*

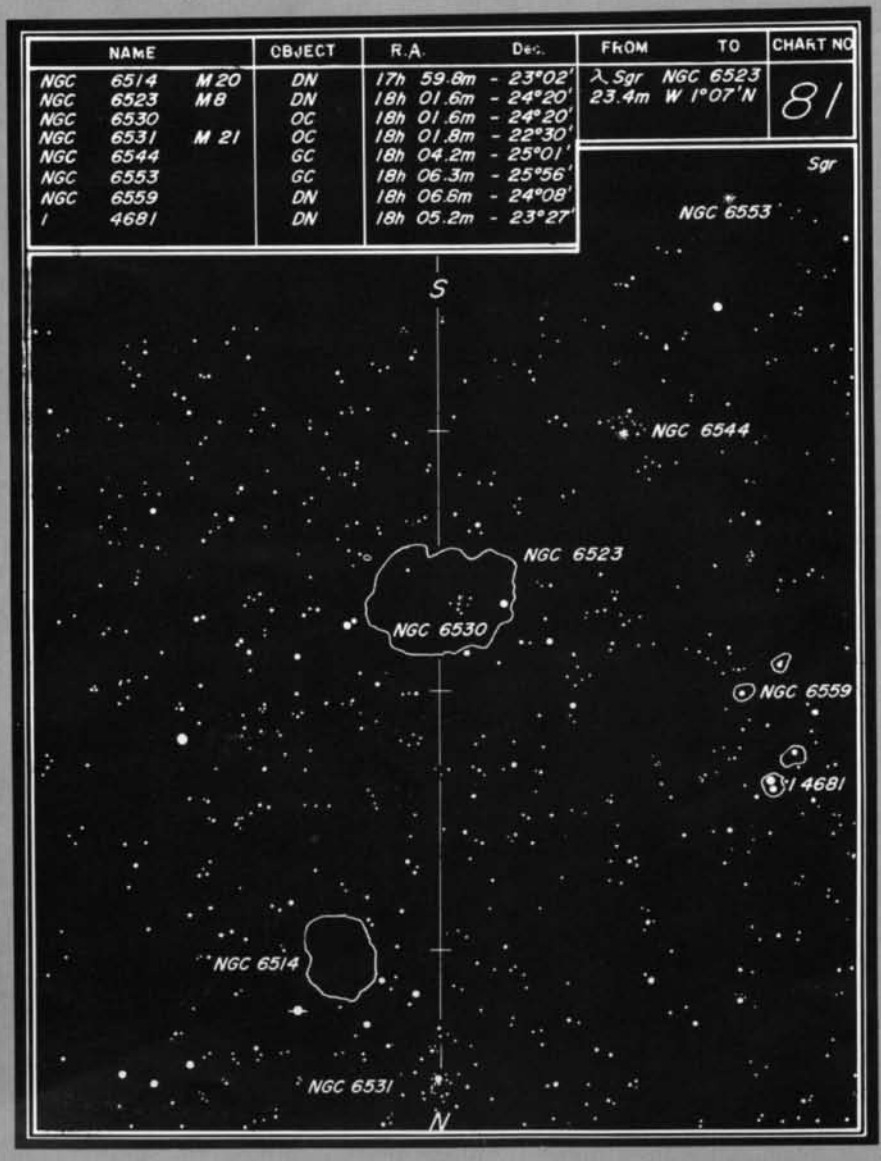


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Photo by R. Potter
The beautiful Veil Nebula in Cygnus
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Rich Zepernick, Cresskill, NJ

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82mm	**$49.95**	

Hypered 2415 film, 36 exp . . . **$9.95** . . . **3/$26**

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DEEP-SKY FINDERSCOPE

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2415, Ultra-fine grain B&W, red sensitive	36	**$9.95**
III a-J, fine grain B&W, blue sensitive for galaxies	20	**$12.95**
Ektachrome 200 prof. 5036, color slides	20	**$9.95**
Fujichrome 400, color slides, "Excellent"	20	**$12.95**
VR1000, fastest of all, color neg for prints	12	**$12.95**
III a-J, 35mm B&W film, unsensitized	20	**$8.95**
III a-J, 2X2" glass plates, unsensitized	36	**$149.95**
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Fujichrome RD100, 120 size, unsensitized	16	**$6.95**
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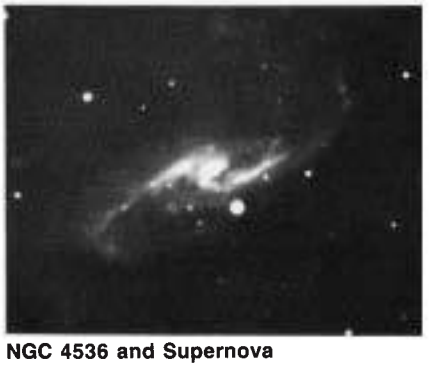
Scanning the Literature

January — June 1983

One of the principal American astronomical journals, the *Publications* of the Astronomical Society of the Pacific (PASP), began monthly publication at the start of this year. This permits more rapid dissemination of research results than with the previous bimonthly issues. Among recent articles of interest to backyard observers and photogaphers is "The Photometric Properties of the Bright Type I Supernova 1981b in NGC 4536" by Ronald J. Buta and Andrew Turner (95:72 January). In the spring of 1981 many amateur observers witnessed this supernova as it peaked at about magnitude 12. The paper includes a photograph of the galaxy and photometric measures for three field stars (V = 7.0, 13.1, and 14.2) and the supernova.

In another of Helmut Abt's series of papers about the publication activity of astronomers, he asks, "At What Ages Did Outstanding American Astronomers



McDonald Observatory

NGC 4536 and Supernova

Publish Their Most-Cited Papers?" (95:113 February). In contradiction to the commonly accepted belief that a scientist's best work is done in his twenties or thirties, Abt found that astronomers published their most valuable papers when they were between 40 and 75 years old!

Two interesting papers are in the *Astronomical Journal* during this period. A potentially important one is "UBVREI Photometric Standard Stars Around the Celestial Equator" by Arlo U. Landolt (88: 439 March). Before 1973, there were two major problems with the UBV set of standard comparison stars: It contained stars too bright to be used with large professional telescopes, and most of the stars were too far north for use in the southern hemisphere. In March 1973 Landolt published the magnitudes of over 600 fainter stars around the celestial equator, ones that solved both of these problems. This list has since become the most frequently cited in the literature. Landolt has now extended this work on a subset of 223 of these same stars to include the R and I passbands of the Kron-Cousins photometric system, which are the red and near-infrared bands in most general use. Additional UBV measures were made to strengthen the precision of these magnitudes. The stars range in brightness from V=7 to V=12.5, while the range in B-V color is from about −0.3 to about 2.0, making them useful for a wide range of observational projects. The mean errors of the standard in V, only 0.013 magnitudes, were achieved by typically measuring each star twenty times on an average of twelve different nights.

A curious galaxy in Canes Venatici is studied in "Surface Photometry of NGC 4656/4657" by L.C. Slayton, R.J. Angione and F.D. Talbert (88:602 May). This galaxy appears in DSM #2 on page 8, and its image is again printed here. The results of their photometric analysis shows that the two NGC numbers apply to parts of the same galaxy, and not an interacting pair of objects as was previously thought. The system strongly resembles the Small Magellanic Cloud and NGC 55, and has a low intrinsic luminosity, about absolute B magnitude −16.7. The authors calculated a distance of about 3.5 Mpc (12.7 million light-years).

Astronomy and Astrophysics is the most widely available continental European journal of astronomy. It sometimes contains articles of interest to amateurs, particularly in its *Supplement Series*. In the first half of 1983 a couple of useful articles appeared here, one of which is "Positions, Magnitudes and Colors for Stars in the Globular Cluster M15" by R. Buonanno, G. Buscema, C.E. Corsi, G. Iannicola, and F. Fusi Pecci (*Ast. & Ap. Supp.* 51:83 January). This work gives UBV magnitudes and relative positions for about 650 stars in this bright globular. The measured stars lie between 1.9′ and 5.0′ from the center

Martin C. Germano

NGC 4656/7: One galaxy?

of the cluster, and range from V magnitude 12.5 on down.

Many observers stumble upon a faint globular cluster located not far southeast of the Lagoon Nebula while scanning this rich Milky Way region. It is the subject of Gonzalo Alcaino's photometric study, "The Globular Cluster NGC 6544" (52:105 April). He gives UBV magnitudes for 164 stars of V magnitudes 12.5 to 18 in and around this obscured cluster. The paper is unusually well illustrated with three photographs that identify the stars, show the field around the object, and show the outer and inner portions of the cluster.

Brian Skiff
421 West Aspen
Flagstaff, AZ 86001

37° 31′ 33″ N

77° 35′ 41″ W

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